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What are massive space rocks made of?

HOW TO SEE SUPERNOVAS

Use your telescope to find the galaxy's most ferocious explosions

DESTINATION MARS

How mankind will reach the Red Planet within your lifetime

+

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Tired of Earth? Get into space!

“There is nothing in this that is beyond our technology; we can do this”
16 Robert Zubrin, Mars Society founder

No other planet orbits closer to us than Earth’s sister planet Venus but it’s our next nearest neighbour Mars that has dominated human imaginations throughout history, from ancient religions to modern day science. Over the centuries humanity has progressed from worshipping Mars to observing Mars to exploring Mars and the next great step for humankind and scientific achievement must surely be setting foot on the surface of the Red Planet.

Plans to send humans to Mars have been in place ever since the Fifties but they were constantly thwarted by myriad problems, from technical and financial through to political. However, the recent advent of private companies with the money and expertise to become serious contenders in the space race have led to a number of changes to the landscape of Martian exploration that are both significant and exciting.

Space X, the company currently sending supply capsules to the ISS, plans to land a rover on Mars in preparation for a long-term manned mission in the near-future, while the Mars One project aims to use similar technology to send a one-way mission as early as 2023. A less permanent solution is offered by millionaire and space tourist Dennis Tito whose Inspiration Mars Foundation intends to launch two astronauts on a flyby mission around Mars even earlier in 2018. Progress towards Mars is being made and made swiftly, so this month we wanted to bring you up to speed on attempts to achieve the next great milestone in space exploration – a manned mission to Mars. Amazingly, it’s one that could even be witnessed in our lifetimes.

Dave Harfield
Editor in Chief

Crew roster

Jonathan O’Callaghan
■ Jonathan blasts off this month with a fascinating explanation of the most amazing rockets ever to leave the Earth

Shanna Freeman
■ Shanna’s research and writing took her 384,400km from Earth this issue to explore our satellite, the Moon

Gemma Lavender
■ Gemma’s contribution this month saw her tasked with exploring manned missions to the Red Planet

Nigel Watson
■ Nigel travels into the future almost every issue and this month he reports back on a boat-probe to Saturn’s moon Titan

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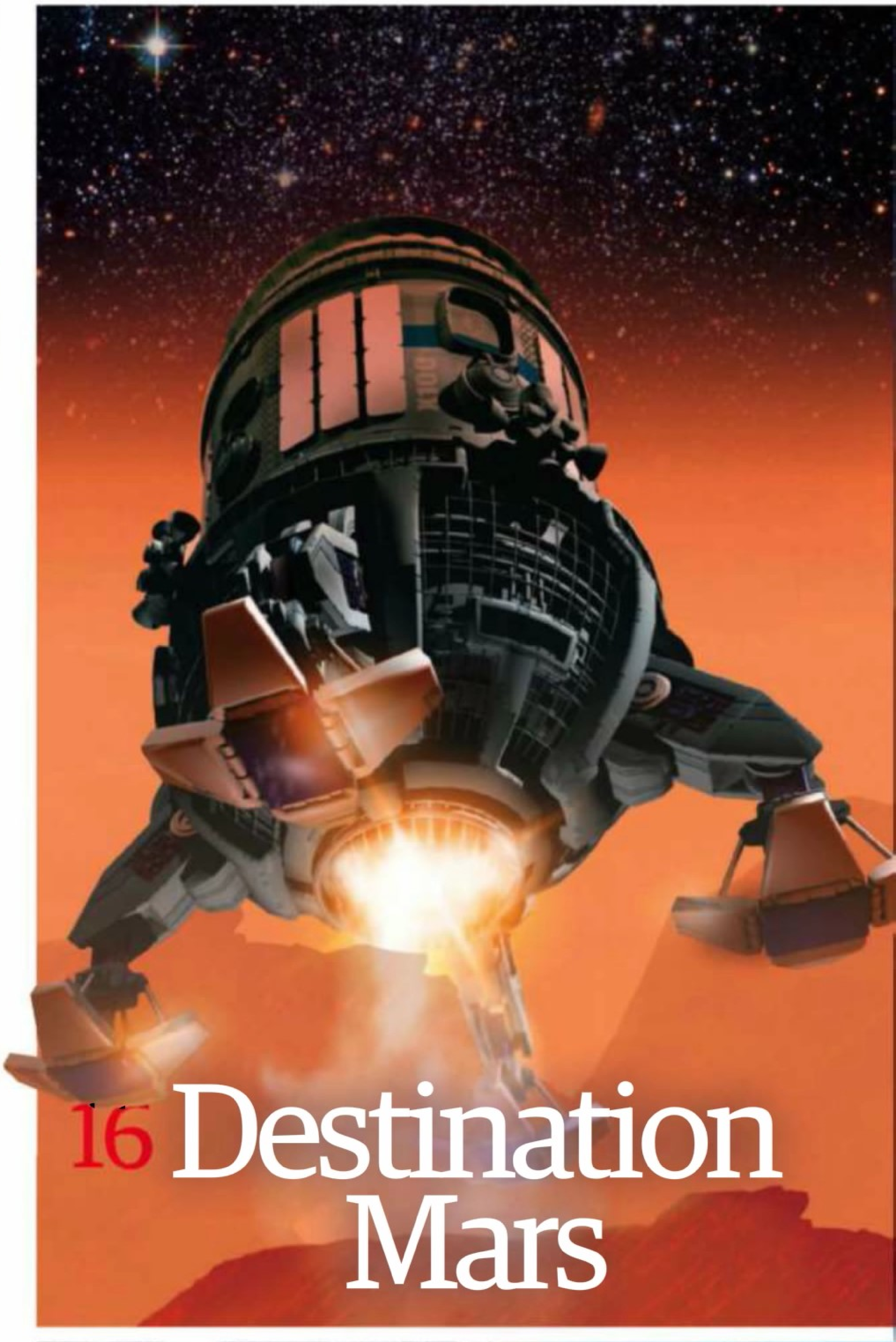

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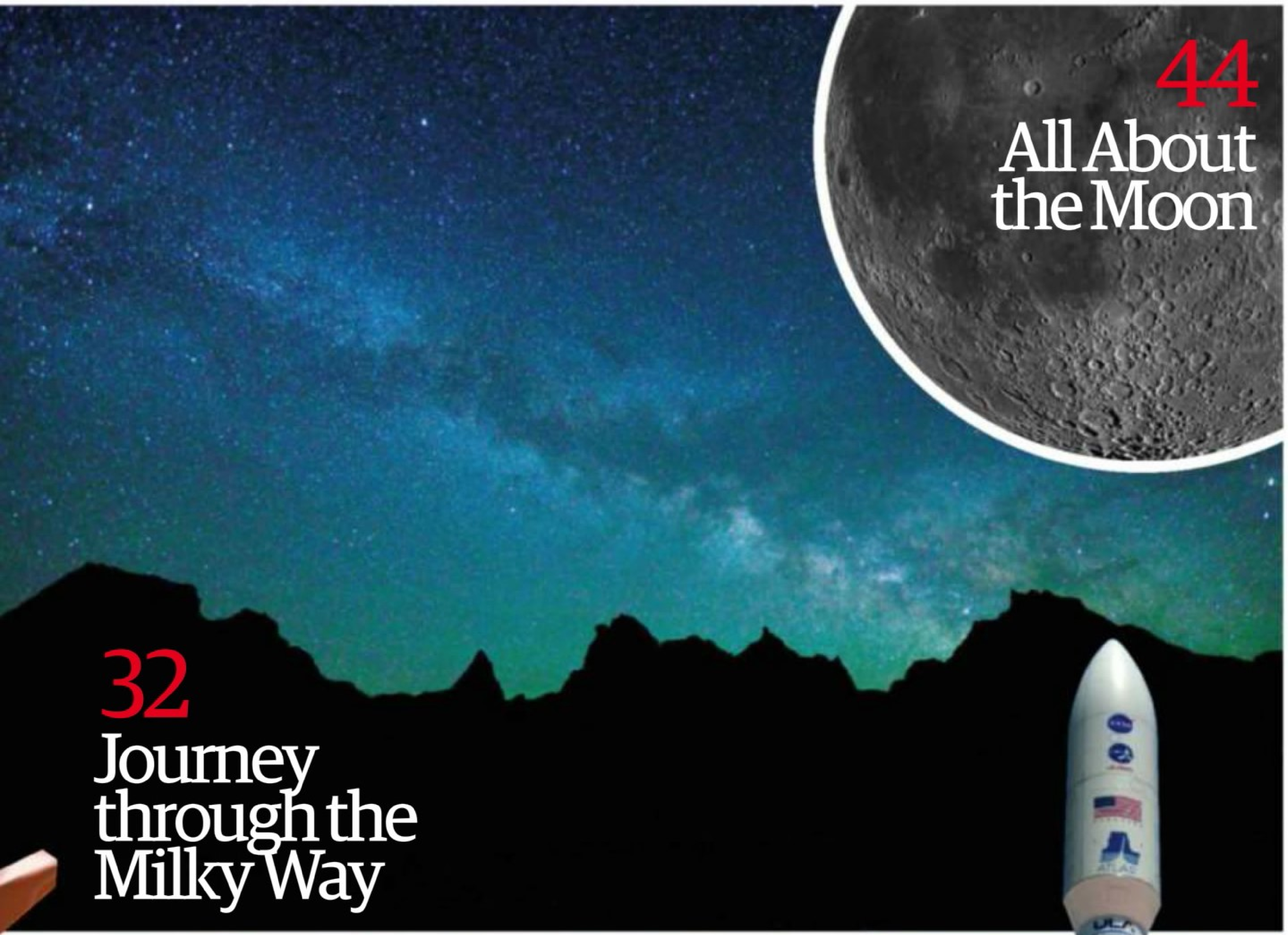

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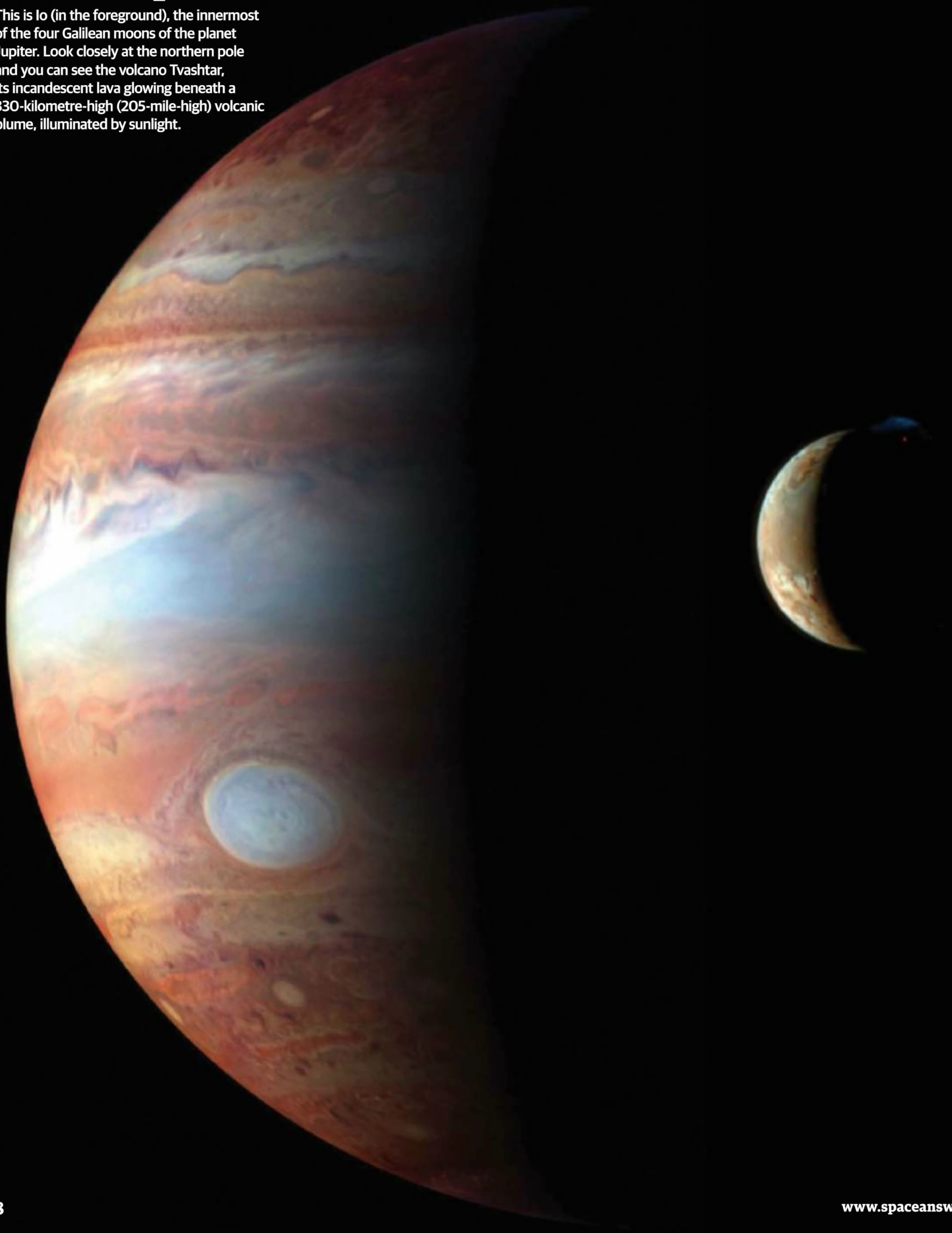
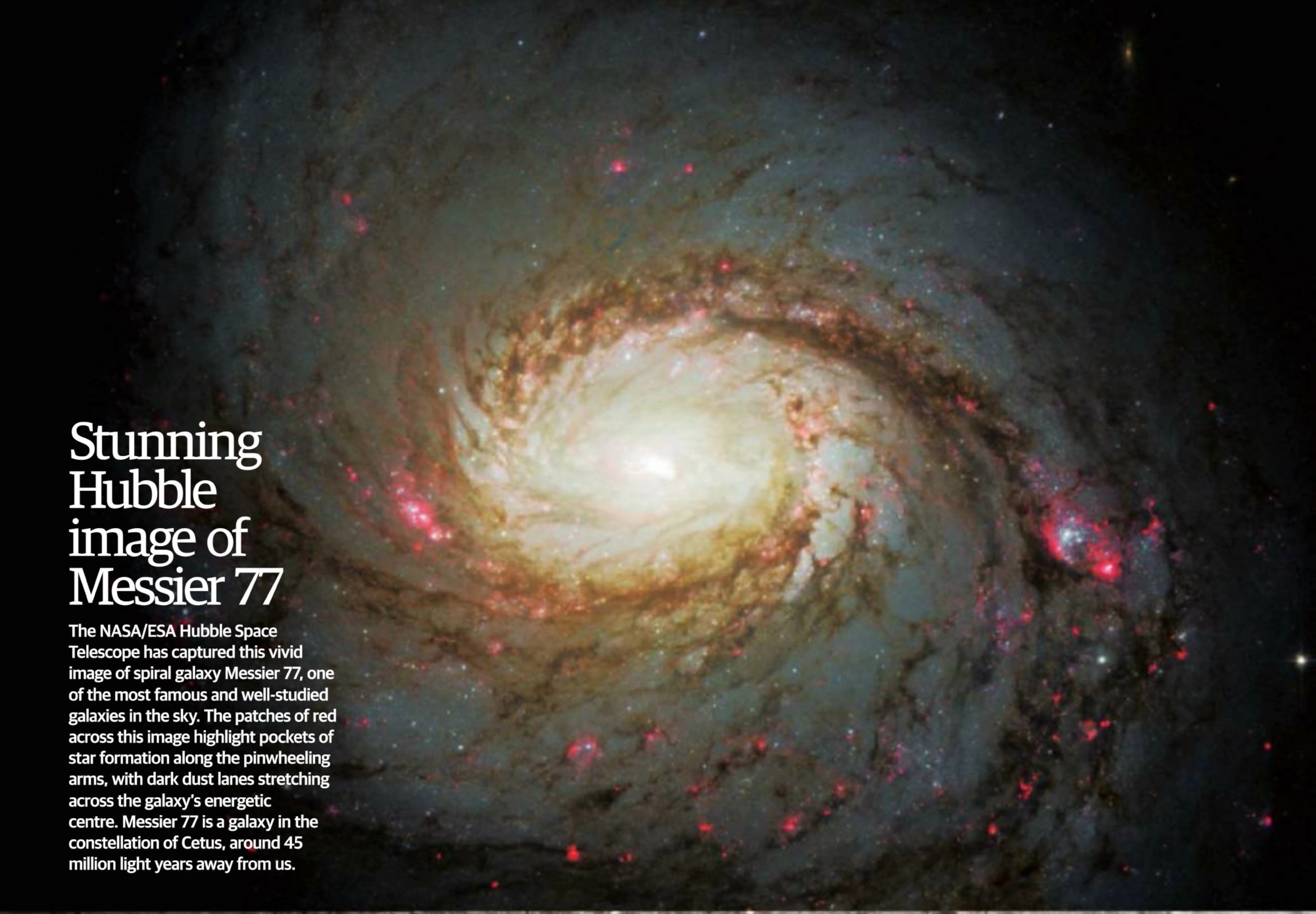
Dragon bids farewell to ISS…

…or more like adieu, as this farewell to the private supply capsule marked the end of just the second of 12 planned cargo missions to the International Space Station. Snapped by commander Chris Hadfield on 26 March, this image shows the Dragon just prior to release by the station's robotic arm. It later splashed down in the Pacific Ocean near Mexico's Baja peninsula.

Io and Jupiter

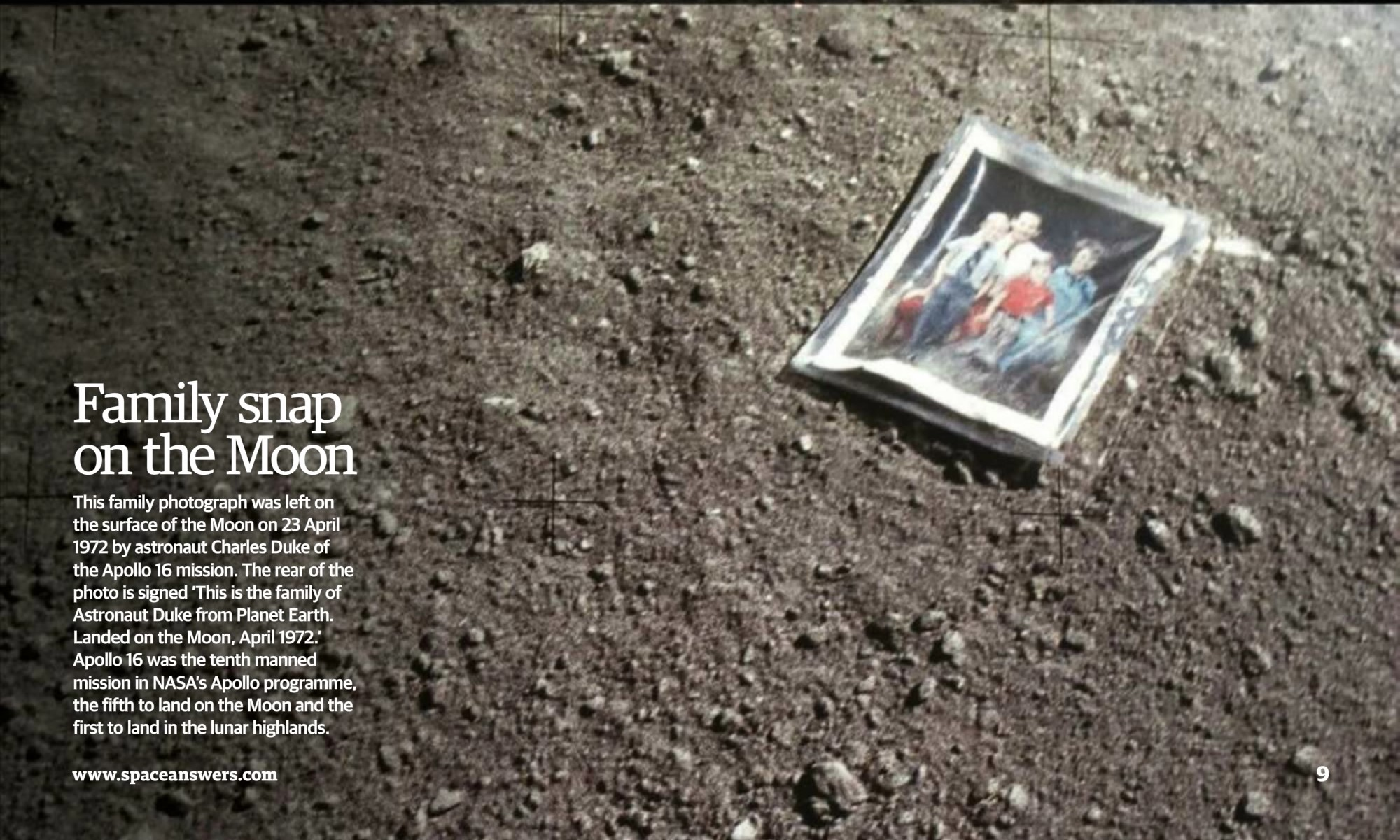
This is Io (in the foreground), the innermost of the four Galilean moons of the planet Jupiter. Look closely at the northern pole and you can see the volcano Tvashtar, its incandescent lava glowing beneath a 330-kilometre-high (205-mile-high) volcanic plume, illuminated by sunlight.





Stunning Hubble image of Messier 77

The NASA/ESA Hubble Space Telescope has captured this vivid image of spiral galaxy Messier 77, one of the most famous and well-studied galaxies in the sky. The patches of red across this image highlight pockets of star formation along the pinwheeling arms, with dark dust lanes stretching across the galaxy's energetic centre. Messier 77 is a galaxy in the constellation of Cetus, around 45 million light years away from us.

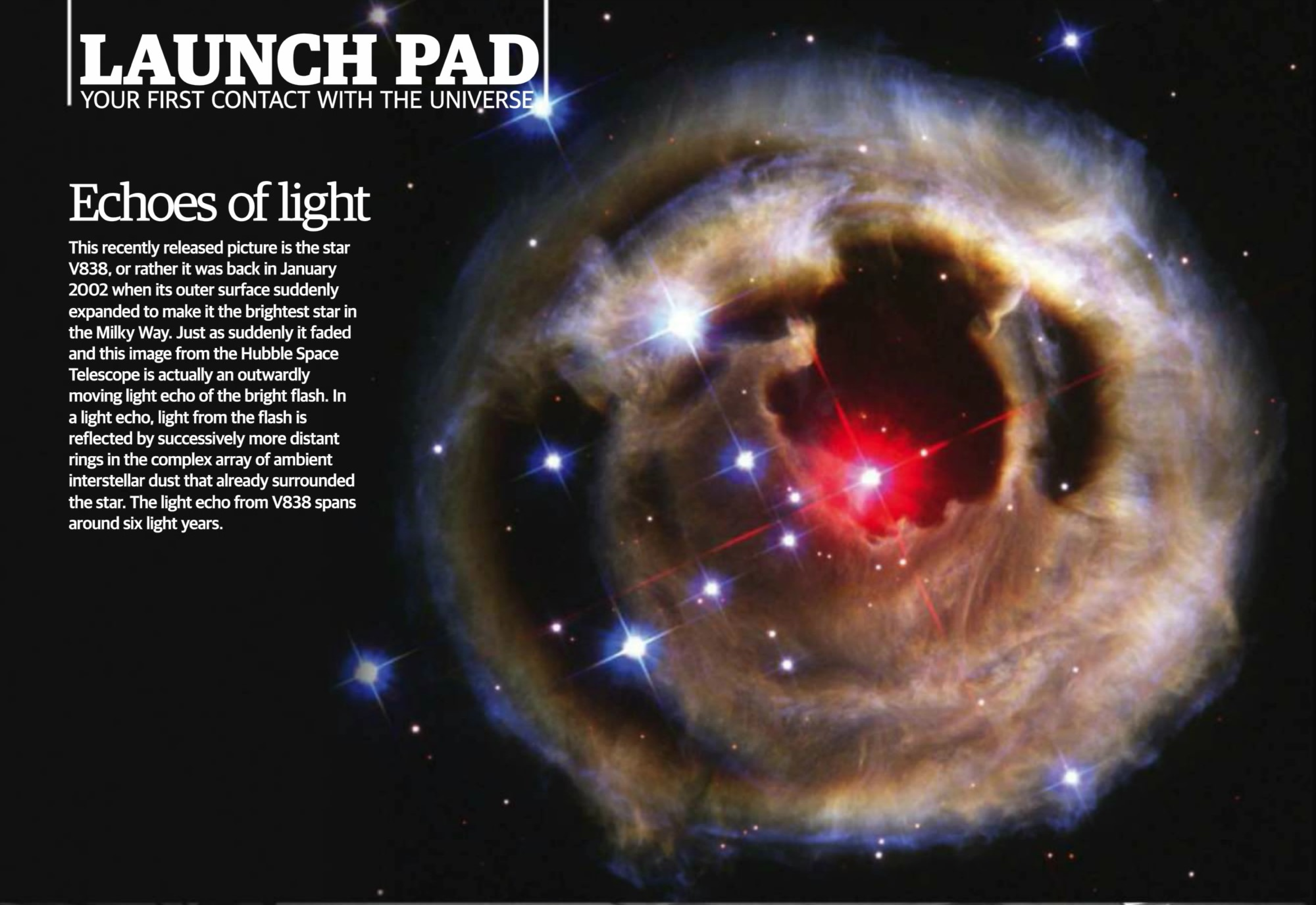


Family snap on the Moon

This family photograph was left on the surface of the Moon on 23 April 1972 by astronaut Charles Duke of the Apollo 16 mission. The rear of the photo is signed 'This is the family of Astronaut Duke from Planet Earth. Landed on the Moon, April 1972.' Apollo 16 was the tenth manned mission in NASA's Apollo programme, the fifth to land on the Moon and the first to land in the lunar highlands.

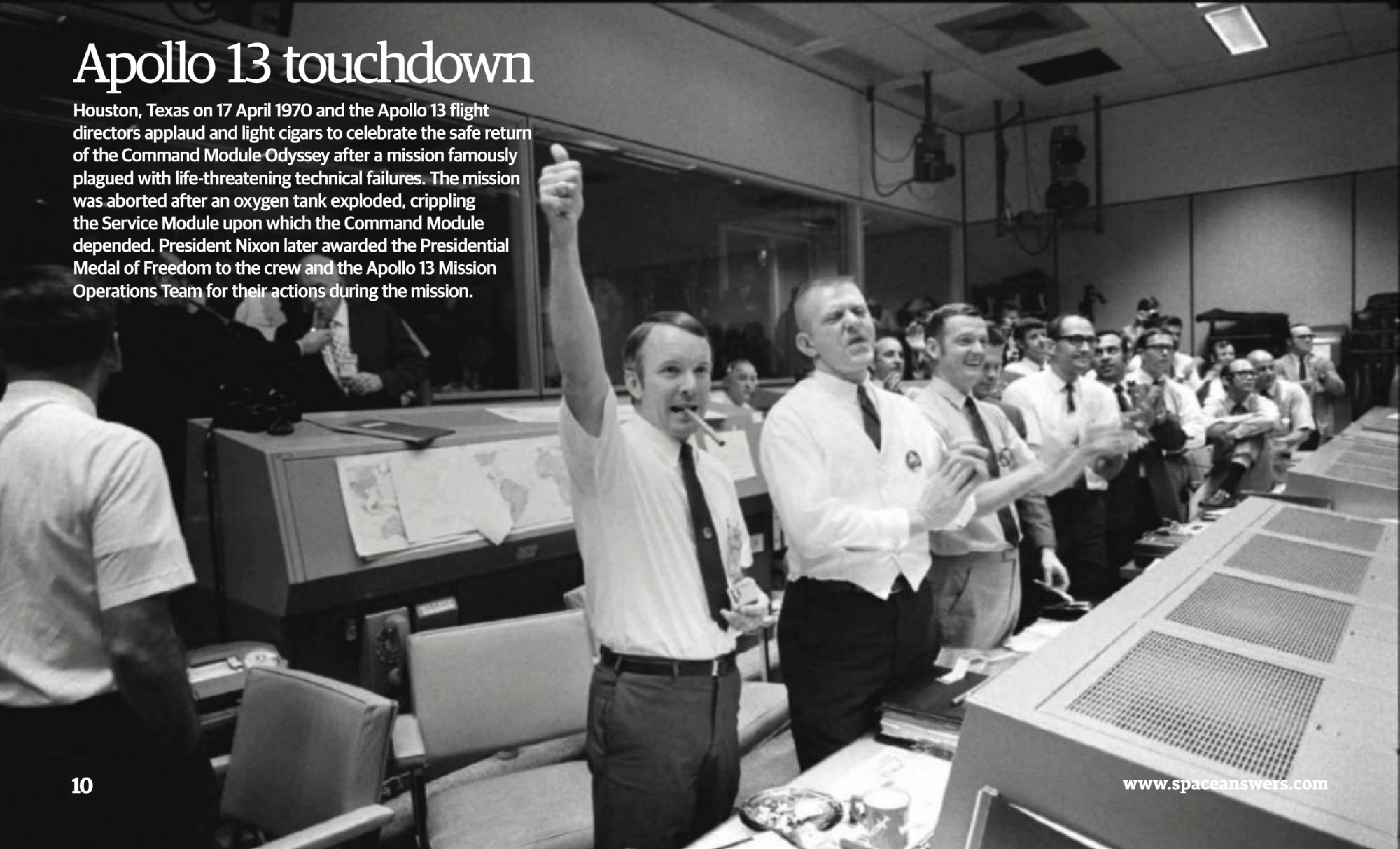
Echoes of light

This recently released picture is the star V838, or rather it was back in January 2002 when its outer surface suddenly expanded to make it the brightest star in the Milky Way. Just as suddenly it faded and this image from the Hubble Space Telescope is actually an outwardly moving light echo of the bright flash. In a light echo, light from the flash is reflected by successively more distant rings in the complex array of ambient interstellar dust that already surrounded the star. The light echo from V838 spans around six light years.



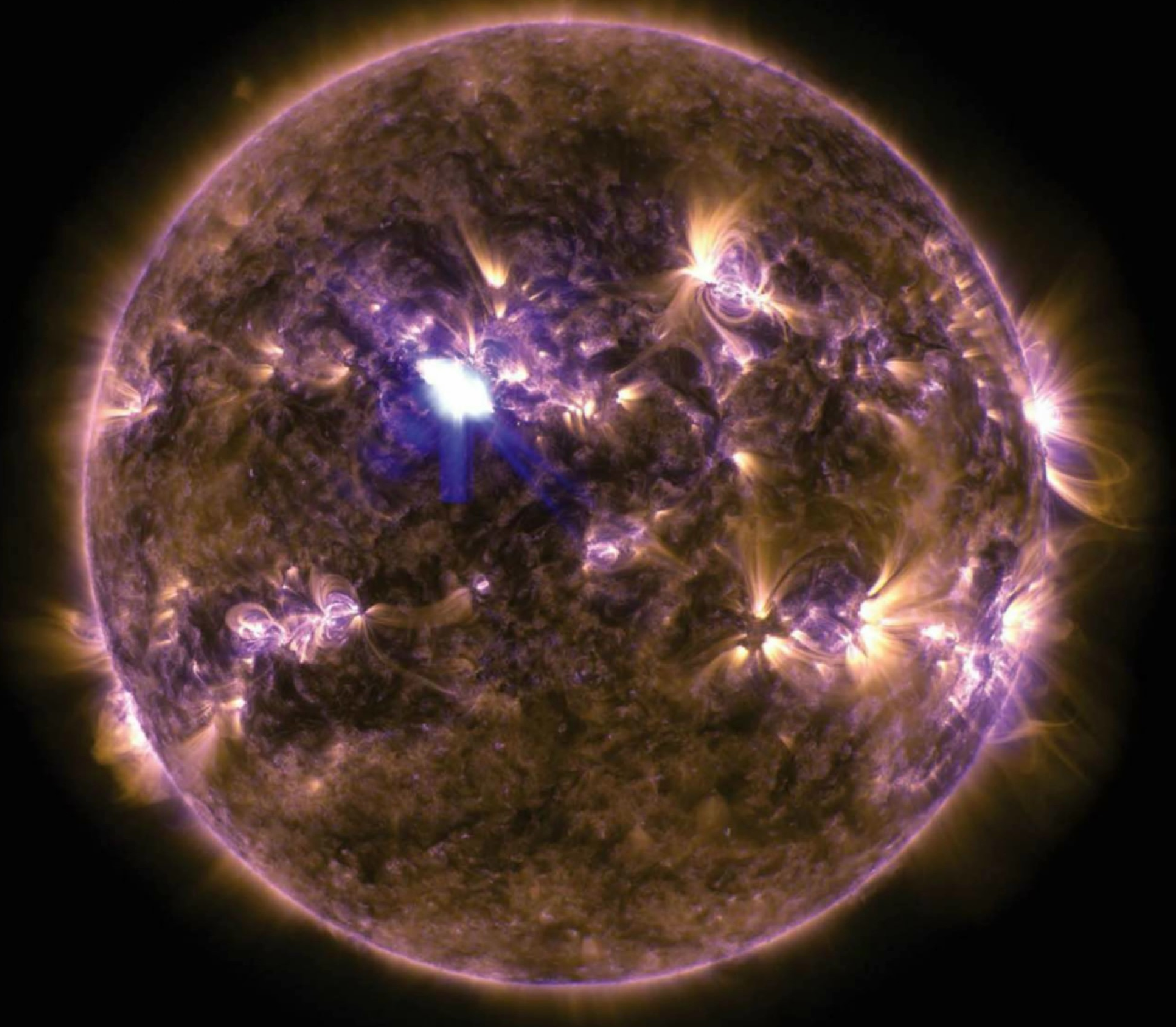
Apollo 13 touchdown

Houston, Texas on 17 April 1970 and the Apollo 13 flight directors applaud and light cigars to celebrate the safe return of the Command Module Odyssey after a mission famously plagued with life-threatening technical failures. The mission was aborted after an oxygen tank exploded, crippling the Service Module upon which the Command Module depended. President Nixon later awarded the Presidential Medal of Freedom to the crew and the Apollo 13 Mission Operations Team for their actions during the mission.



Solar flare of the year

The month of April saw the Sun give up its strongest solar flare of 2013, accompanied by a coronal mass ejection (CME) shot out towards planet Earth and the rest of the Solar System. This false colour image from the Solar Dynamics Observatory captured the relatively moderate M6.5 class flare erupting from the active AR11719 region near the centre of the solar disc, which triggered some stunning aural displays on Earth.



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Dark matter on the brink of discovery

A space station experiment offers up compelling hints that a large part of the universe is invisible dark matter

Scientists may have uncovered the best indirect evidence for the existence of mysterious dark matter, which has proven inscrutable to our experiments before now. It's all thanks to a $1.5 billion (£980 million) experiment called the Alpha Magnetic Spectrometer, or AMS, which is currently attached to the International Space Station (ISS) orbiting Earth about 400 kilometres (250 miles) up.

Nobody knows what dark matter is, as we cannot see it. However, it exerts a gravitational force that leads many astronomers to believe that dark matter must exist in order to explain the anomalous motions of stars on the edges of galaxies, or galaxies on the boundary of galaxy clusters. Before the AMS, our best evidence for dark matter came from colliding galaxy clusters, which behaved in such a way that strongly indicated the presence of invisible matter.

The AMS is designed to detect cosmic rays, which are energetic space particles such as protons and electrons. In a year and a half since it was launched to the ISS it has detected 25 billion cosmic rays and 400,000 of these were a type of particle called a positron. This is the antiparticle to the electron, which means it is like an electron but has a positive electric charge rather than a negative one. Many of the positrons fell into an energy range of between 10 and 250 GeV, which is what would be expected from particles of dark matter colliding into one another, releasing positrons in the process.

> "Over the coming months AMS will tell us conclusively whether these positrons are a signal for dark matter..."

The experiment's lead scientist – Nobel prize winner, Professor Samuel Ting of the Massachusetts Institute of Technology (MIT) - is at pains to point out this is not a definitive detection of dark matter, which has eluded astronomers for decades. For example, the positrons could also be coming from spinning pulsars.

"Over the coming months AMS will be able to tell us conclusively whether these positrons are a signal for dark matter, or whether they have some other origin," said Ting. "AMS is the first experiment to measure to one per cent accuracy in space. It is this level of precision that will allow us to tell whether our current position observation has a dark matter origin."

AMS is due to operate on the ISS for another ten years so should have plenty of time to figure out where the positrons are originating from. Even if they are from pulsars it doesn't mean dark matter does not exist - only that certain theories can be ruled out.

That said, some dark matter sceptics support an alternative hypothesis called MOND, which says the effects attributed to dark matter can be explained by tweaking Isaac Newton's original laws of gravity. ●

Samuel Ting of MIT is the principal scientist behind the Alpha Magnetic Spectrometer (AMS) science experiment

Apollo rocket engines are recovered from ocean

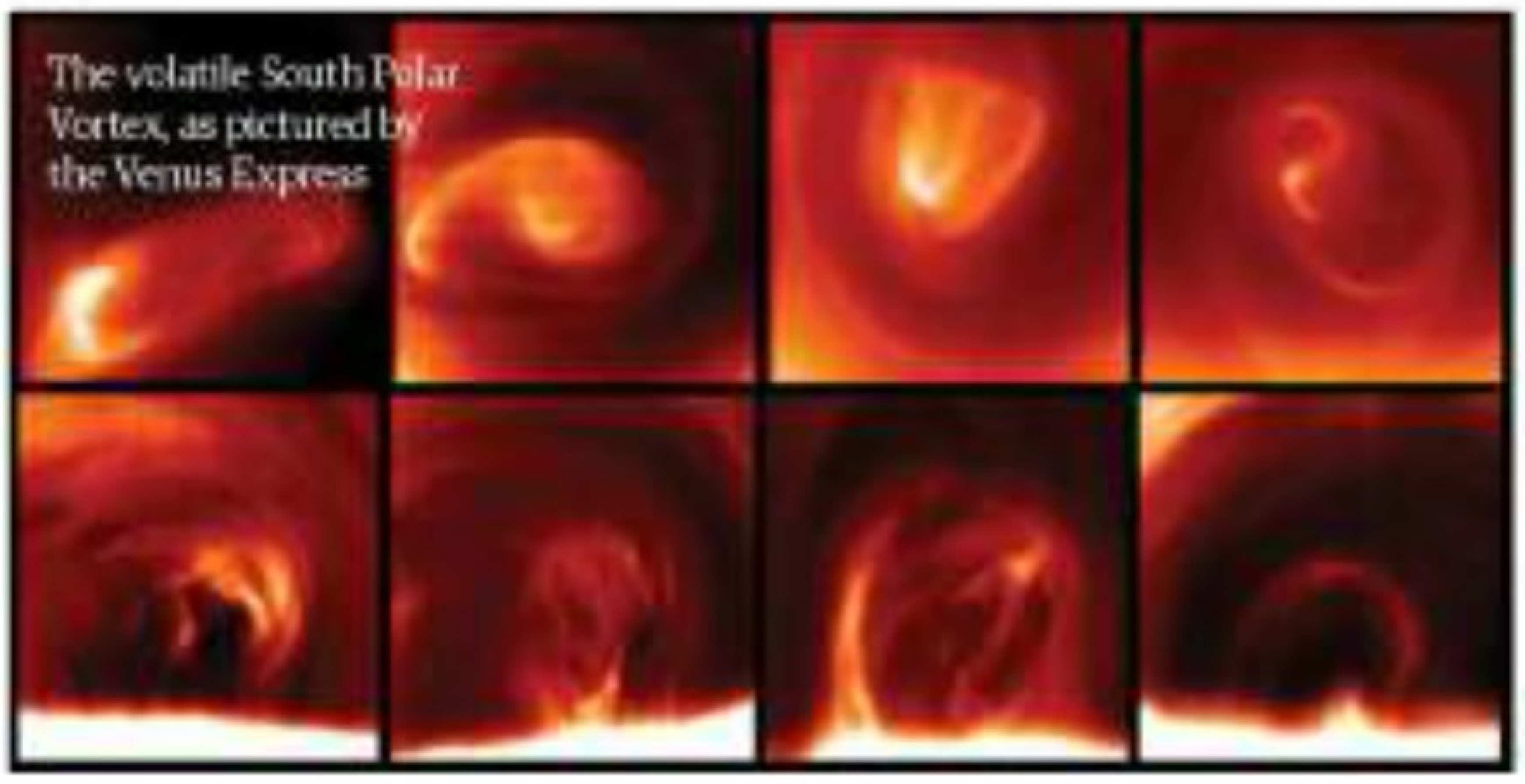
An expedition funded by Amazon founder, Jeff Bezos, has finally received the fruits of its labour as two rocket engines, thought to have been disposed of by the Saturn V rockets during the Apollo missions to the Moon, were retrieved from about 4.8 kilometres (three miles) beneath the Atlantic Ocean.

"Nearly one year ago, Jeff Bezos shared his plans to recover F-1 engines that helped power Apollo astronauts to the Moon in the Sixties and Seventies," says NASA administrator, Charles Bolden.

The engines, which illustrate the historic moment that humans were propelled to the Moon, are intended to be restored for public display. However, after spending more than 40 years on the ocean floor it may not be possible to revert the motors back to their former glory.

"Many of the original serial numbers are missing or partially missing, which is going to make mission identification difficult," says Bezos in a posting on the project's website. "The technology used for the recovery is in its own way as otherworldly as the Apollo technology itself. The objects themselves are gorgeous."

Bezos states that his team is bringing back enough major components to make public displays of two F-1 engines. "The upcoming restoration will stabilise the hardware and prevent further corrosion. We want the hardware to tell its true story, including its re-entry and subsequent impact with the ocean surface." ■



The volatile South Polar Vortex, as pictured by the Venus Express

Venus superstorm is in constant flux

New observations of Venusian clouds reveal true scale of South Polar Vortex

The European Space Agency's Venus Express spacecraft has revealed that Venus's stormy cyclone, the South Polar Vortex, is considerably more unpredictable and aggressive than previous observations suggest.

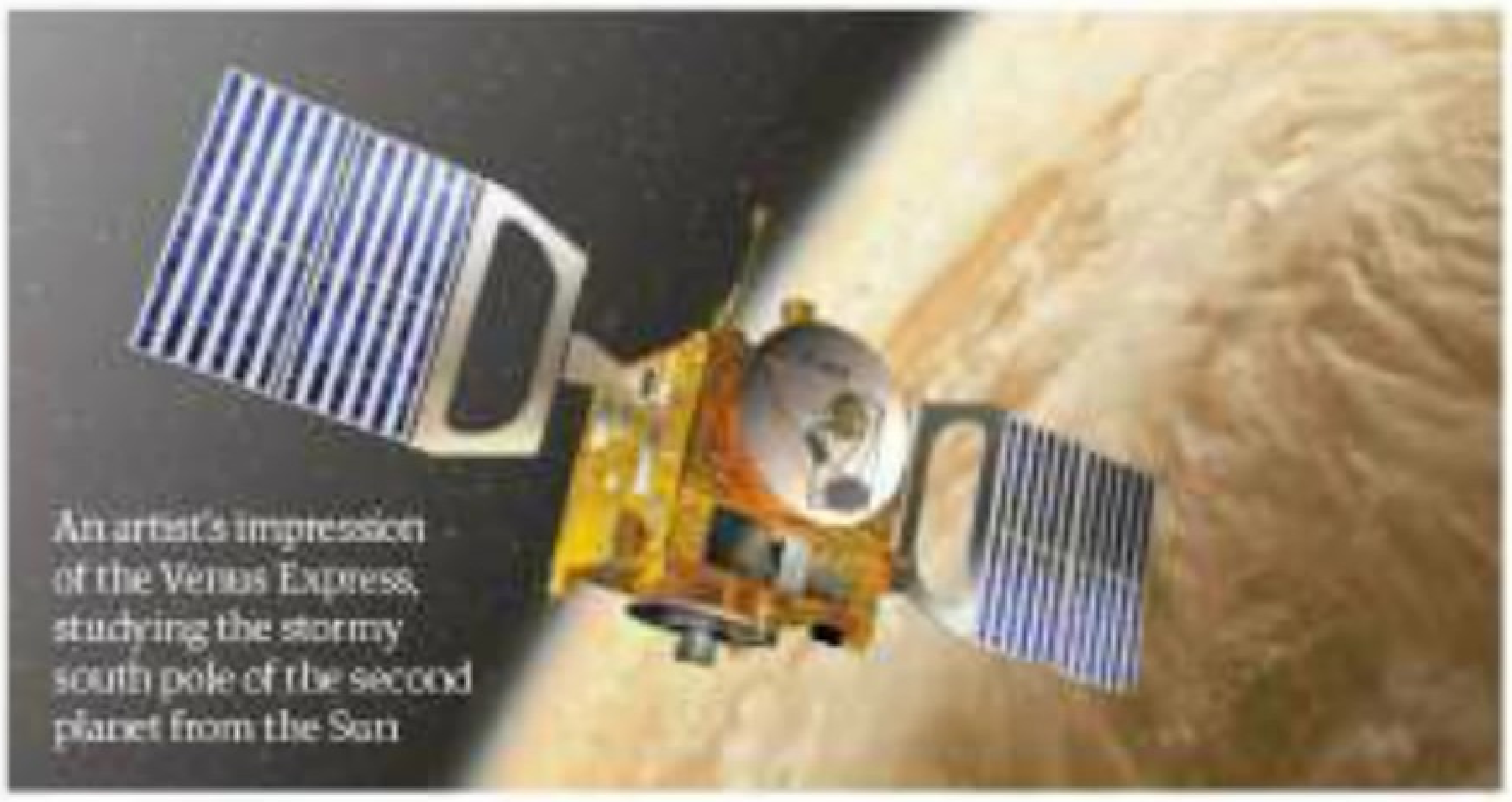
Extending vertically in Venus's atmosphere, the monstrous storm towers over 21 kilometres (13 miles), slicing through a region of extremely turbulent yet permanent clouds with an eye that covers 2,250 x 1,430 kilometres (1,400 x 890 miles).

Penetrating through the dense carbon dioxide atmosphere with the help of infrared instrument VIRTIS on board the orbiter, the central region of the vortex was found to be rampaging around the planet's south pole at varying speeds through cloud layers separated by around 21 kilometres (13 miles). What's more, the vortex changes in shape and size daily.

"The different motion of the vortex at two different levels was an unexpected result," says Itziar Garate-Lopez, planetary scientist at the Escuela Técnica Superior de Bilbao Universidad del País Vaso in Spain. "The different wanders [of the clouds] around the pole and the daily changing shape might be due to the turbulent convective region between both levels, which converts the vortex into a large-scale 'twisted tube' that is constantly evolving." However, Garate-Lopez and her team are unable to explain why the vortex is variable enough to alter its form in a single day.

But further research is planned. "Now that we know the detailed information about the wind's motions, we are interested in obtaining some temperature [data]," she says. "[With this] we could study the dynamic reasons behind the phenomena." ■

> "The different motion of the vortex at two different levels was an unexpected result"



An artist's impression of the Venus Express, studying the stormy south pole of the second planet from the Sun

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Black hole and red dwarf found in orbit at record speed

The identification of an odd couple pairing of a black hole and a red dwarf star has set a new record for the fastest orbiting X-ray binary system, circling at a rate of one orbit every 2.4 hours.

Herschel finds youngest stars

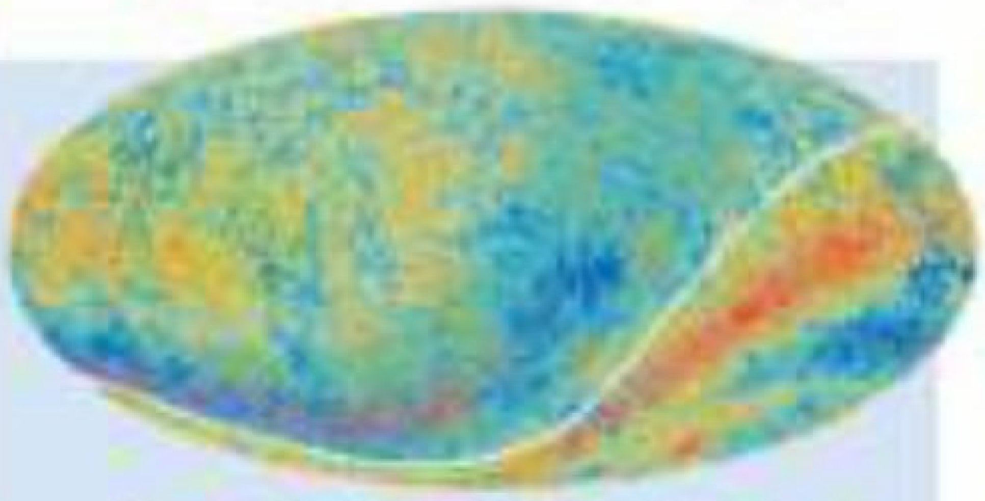
Wrapped up in a blanket of gas and dust, a nursery of the youngest stars ever seen has been uncovered by the Herschel Space Telescope in the constellation of Orion 1,600 light years away.

Comet could smash into the Red Planet

Comet 2013 A1 (also known as Siding Spring) is set for a close encounter with Mars in October 2014, when it will pass about 48,890 kilometres (31,000 miles) from the surface. An impact with the Red Planet's surface, although unlikely, is a possibility.

Martian probe readies for late 2013 launch

NASA's Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft, which will study the Martian upper atmosphere, is assembled and is now undergoing environmental testing ahead of its scheduled launch in November 2013.



Temperature variations are shown from blue (coldest) to red (hottest)

Planck indicates universe is 80 million years older

The ESA's Planck Surveyor satellite has captured the most detailed map of the oldest light in the universe, which was emitted just 380,000 years after the Big Bang. Called cosmic microwave background (CMB) radiation, it shows the cooling of the epic event thought to have kick-started the universe.

The colours are false, but show areas of slightly greater or lesser temperature, which correspond to denser or sparser areas of the cosmos when the light was produced. The denser areas grew over billions of years to become galaxy clusters, while the sparser areas expanded to become the great voids between them.

So what does this colourful baby picture of the universe tell us? Scientists have inferred from it that the cosmos is made of 4.9 per cent normal atoms, 26.8 per cent dark matter and 68.3 per cent dark energy. They have also measured something called the Hubble Constant, which describes how fast the universe is expanding. They found it to be 67.2 kilometres (41.8 miles) per second per megaparsec, which is a slower rate than previously believed, so it must have been expanding for longer. This means the universe has to be older than we thought, putting it at an age of about 13.8 billion years.

It threw up some mysteries too, such as a giant cold spot that current models of the universe cannot explain. Scientists also discovered that the size of the temperature differences is bigger on one side of the sky than the other and is aligned with the plane of the Solar System, but why this is the case remains a puzzle so far. ■

The docking of the Soyuz spacecraft with the ISS was completed in just six hours

Soyuz docks with ISS in record time

The Russian spacecraft cuts the Earth-to-ISS transit from days to hours

Reducing a complicated and lengthy 30 orbits down to four, a Soyuz space capsule carrying three astronauts as part of Expedition 35 successfully docked with the ISS on 29 March, completing a journey that normally takes two days in a mere six hours.

Welcoming new crew members, Russia's Pavel Vinogradov and Alexander Misurkin along with the American Chris Cassidy, were Expedition 35 commander Chris Hadfield and flight engineers Roman Romanenko and Tom Marshburn. It is scheduled that the new astronauts will return to Earth this September, while Hadfield and his colleagues will head home earlier in May.

The Soyuz capsule, which was launched from the Baikonur Cosmodrome in Kazakhstan, managed to cut 45 hours flight time by performing intricate manoeuvres as it entered orbit - a shortened route that was tested three times by unmanned Russian Progress ships carrying supplies into low-Earth orbit.

Taking full advantage of their time on board the habitable platform, the six-strong crew will undertake 137 investigations on the US portion of the ISS and 44 on the Russian part.

According to a statement released by NASA, these experiments will assist in our understanding of biological and physical sciences, Earth observation as well as technology development. ●

A new third class of supernova is revealed

Iax supernovas set to shake up the astronomy world

Here material from a sizzling hot, blue helium star is pulled towards a white dwarf

A new flavour of supernova has been uncovered by observations carried out by the Harvard-Smithsonian Center for Astrophysics, led by Ryan Foley.

Called Type Iax, it's unlike any other supernova, occurring in binary star systems of a white dwarf and a normal star that has shed its outer layers to expose a helium heart.

"Eventually, one [star] ran out of the hydrogen in its core and became a red giant. When this happened, it got bigger - big enough that the outer, nebulous layers of the star surrounded the other star [the common envelope]," Foley tells us. "During this phase, the two stars get closer together, and the other hydrogen-rich layers of the smaller star can be transferred to the bigger star. Eventually the outer layers of the first star were expelled as a planetary nebula and the remaining core of the star is a white dwarf and the other star has lost its hydrogen layers." ■

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Destination Mars

Written by Gemma Lavender

With private space enterprises and NASA planning manned missions to Mars in the coming years, **All About Space** discovers how the world's leading space explorers will take the first humans to the Red Planet

It was former Apollo astronaut and second man on the Moon Buzz Aldrin who uttered the words, "Forget the Moon, let's head to Mars!" This is something that mankind has been working to achieve since the Sixties. Fleets of flyby missions, orbiters, rovers and landers have been sent on one-way missions to shape our understanding of the Red Planet, setting down the groundwork that will one day lead to the moment an astronaut sets foot on Martian soil.

At an average distance of around 225 million kilometres (140 million miles), Mars might not be as close to the Earth as the Moon or Venus, but the ruddy-coloured planet's potential to provide us with information to sate our appetites for knowledge as well as the opportunity to expand our species to another world, today encourages generations of scientists to overcome this distance with relative ease. However, it was not always this way.

The Soviet Union was the first country to launch robotic missions to Mars, with a number of failed launches and probes in the Sixties. By the Seventies, however, they had competition from the Americans. With two countries setting their sights on the Red Planet, the race was well and truly on, but who would get there first?

On 19 May 1971, the USSR's Mars 2 successfully raced through the last of Earth's atmosphere with the Red Planet in its sights. Russia was in with a good chance of winning this round of the Space Race. With the successful launch of Mars 3 taking place a mere nine days later, this only reaffirmed the Soviets' confidence.

However, on 30 May 1971 NASA released Mariner 9 into the skies above Cape Canaveral, hot on the heels of Mars 2 and Mars 3. It reached Mars by 14 November of the same year, beating the sluggish Mars 2 and 3 by a few weeks. Even so, Mariner 9 had to wait out months of relentless dust storms raging across Mars before it could take any of the 7,329 clear images of the Red Planet that it ultimately beamed back to anxiously waiting scientists on Earth. It saw river beds, craters, canyons, great extinct volcanoes such as Olympus Mons, as well as obvious signs of erosion from water and wind.

Following Mariner 9's successful visit, in 1975 NASA launched the twin Viking missions, each one combining an orbiter and lander. But that was it until the mid-Nineties. Since then several robots have been sent to Mars, determined to be the first to underpin the principles which will one day allow humans to set foot on the planet's surface. Satellites have included NASA's Mars Global Surveyor and Mars Reconnaissance Orbiter, and the ESA's Mars Express, as well as the successful Phoenix and Pathfinder landers, while the Spirit, Opportunity and Curiosity rovers touched down on Mars to inspect the Martian soil for signs of life and to take a few snaps of their new home.

However, as we push for greater feats the rovers don't seem to be enough. We need something more sophisticated, according to advocate of the manned exploration of Mars and American aerospace engineer, Dr Robert Zubrin of the Mars Society. We need to go to Mars ourselves.

"I do favour sending robots to Mars and I am very happy that we're doing that," says Zubrin. "They are just the advance scouts and you know, the rovers, I love them, but there's nothing they can do that we [humans] couldn't do a thousand times faster." While the work of the rovers has provided us with an incredible amount of information, signatures of past life such as fossils could easily be overlooked by the robots. "You could parachute 100 rovers [to Mars] and you would never find a fossil," Zubrin explains. "Finding fossils involves hiking through lots of terrain, it involves pick and pickaxing work and it involves diligent work such as carefully splitting open shells to find preserved fossils. This is way beyond the ability of robotic rovers and if you're talking about whether humans could settle on Mars, then clearly, you have to send humans."

So to Mars humans must go. And in a change of dynamic, agencies and organisations are looking past unmanned missions and instead are focusing on landing the first man on the Red Planet in a step that makes science fiction a reality. The feat has become a race once again.

The Martian atmosphere makes landing difficult, it's too thin to provide useful deceleration like Earth's but thick enough to destroy an unprotected spacecraft

The Orion module replaces the now cancelled Constellation Program as our future hopes to send man to Mars

Zubrin thinks he knows how to win the race. In the Nineties he developed a daring plan that he called Mars Direct. "The basic idea of the Mars Direct mission is to explore Mars with a travel-light philosophy," he says. "Rather than building giant spaceships loaded with all of the food, water, air, fuel and oxygen required for a round-trip mission, we try to make the most important of these on Mars."

For example, Zubrin proposes that an unmanned mission go ahead first, carrying with it an Earth-return craft and the ability to make rocket fuel on Mars by reacting hydrogen with the carbon dioxide in Mars's atmosphere to create the methane and oxygen rocket propellant and oxidiser. "So now you have a fully fuelled Earth-return vehicle waiting on the Martian surface," he says. "Then you shoot the crew out to Mars and because the return vehicle is waiting on Mars, they don't need to fly to Mars on a giant spaceship, they just fly to Mars in a habitation module that lands in the vicinity of the Earth-return vehicle."

After 18 months on the surface, the astronauts then head home in the Earth-return vehicle, leaving the habitation module on the Red Planet. But then a second manned mission is launched, delivering another habitation module to the surface, and then a third and a fourth. "Before long you have the first human settlement on another world," says Zubrin. "There is nothing in this that is beyond our technology; we can do this."

Indeed, other organisations are clamouring to be the first. SpaceX's Elon Musk has already stated that he intends to go to Mars, while

"I do favour sending robots to Mars… but they are just the advance scouts"

Dr Robert Zubrin

The NDX-1 spacesuit, designed by aerospace engineer Pablo de Leon for possible use on Mars, was able to endure the icy temperatures and battering winds during tests in Antarctica

Manned missions to Mars

The leading candidates in the new race to Mars

1. Inspiration Mars

With the intention of sending a man and a woman on what has the makings of a historic mission lasting 501 days, Inspiration Mars intends to safely return its crew to Earth after they fly within 160 kilometres (100 miles) of the Red Planet, using technologies derived from NASA and the International Space Station. The plan is to use the gravitational influence of Mars to slingshot their manned vehicle onto a return course back to Earth. They will not land on Mars. The ship's inflatable habitat module will be deployed after launch and detached prior to re-entry into our planet's atmosphere.

2. SpaceX

SpaceX is the world's first privately held company to send cargo to the International Space Station and now the company's founder and CEO Elon Musk intends to send a mission to Mars. First will be a sample-return mission called Red Dragon, that will also look for signs of life. Its long-term plans, however, are to send a manned mission to Mars in a modified version of its already built Dragon capsule. The intention is for the capsule to descend through the Martian atmosphere and land on the rocky surface without the need for a parachute. The capsule's own drag may slow it down enough to allow retro-propulsion thrusters for a controlled enough descent. Eventually SpaceX wants to shuttle 80,000 people to Mars with the intention of colonising the planet.

3. NASA

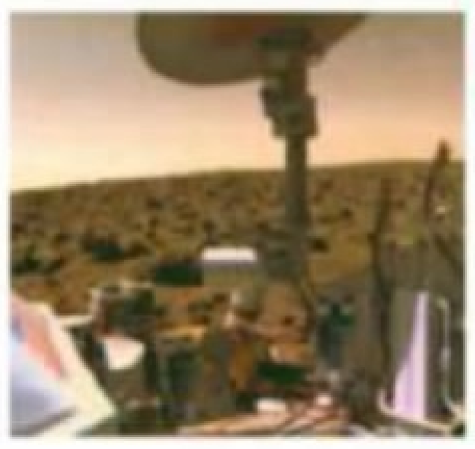
The National Aeronautics and Space Administration, NASA, is the world leader in Mars exploration. Its most recent development to send humans to Mars in a 2030 timeframe is also currently under review. One possibility is the Orion Multi-Purpose Crew Vehicle that was announced by NASA in 2011. It is hoped that the Orion capsule will be able to carry between two and six astronauts sometime after 2020. It is intended that the 8,900-kilogram (19,600-pound) module will be able to return to Martian orbit using methane propellant made from Mars's soil. Image 3 shows the recent Orion drop test where scientists used a mock-up of the Orion crew module to simulate various water-landing scenarios to account for the different velocities, parachute deployments, entry angles, wave heights and wind conditions on Mars.

4. Mars One

Adamant that the technologies to land the first humans on Mars exist, Dutch start-up Mars One aims to spend an estimated $6 billion to initially send four individuals to the Red Planet. They will be tasked with setting up a habitable outpost based on ready-made hardware that will be sent to the planet in advance. After installing their habitat, the members of the first colony outside of Earth will be expected to grow their own food, mine their own water and oxygen, perform research and, of course, explore a whole new planet.

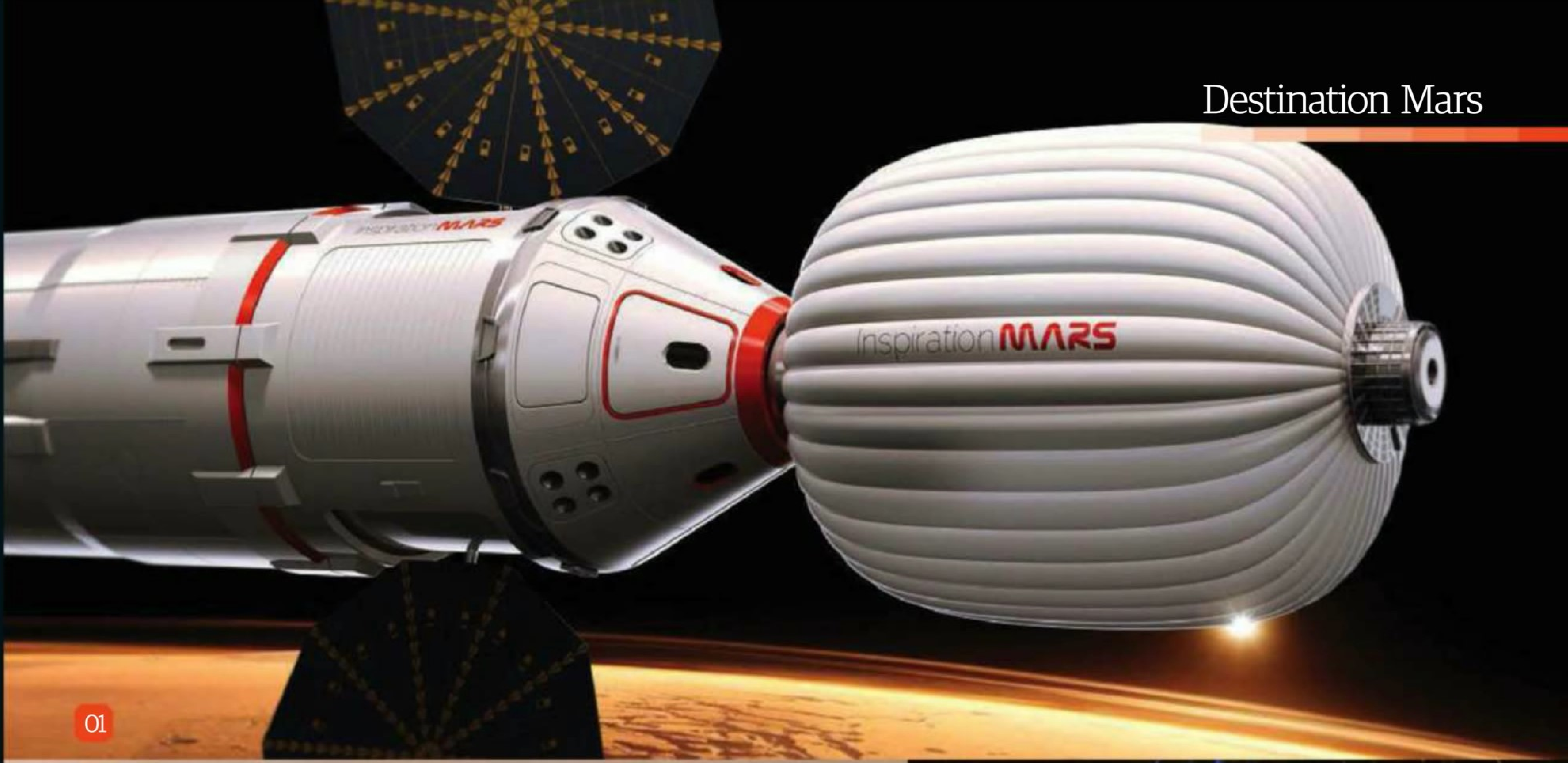
"SpaceX's long-term goal is to colonise the Red Planet"

1971
Mars 3
This was the first spacecraft to achieve a soft landing on the surface of Mars but a great dust storm caused a communications failure.



1976
Viking 1 & 2
The Viking programme returned hi-res images, studied the surface and atmosphere and attempted to search for life on Mars.

1997
Sojourner
Sojourner was the first rover to touch down on Mars. It analysed the atmosphere, climate and make-up of the planet's rocks and soil.



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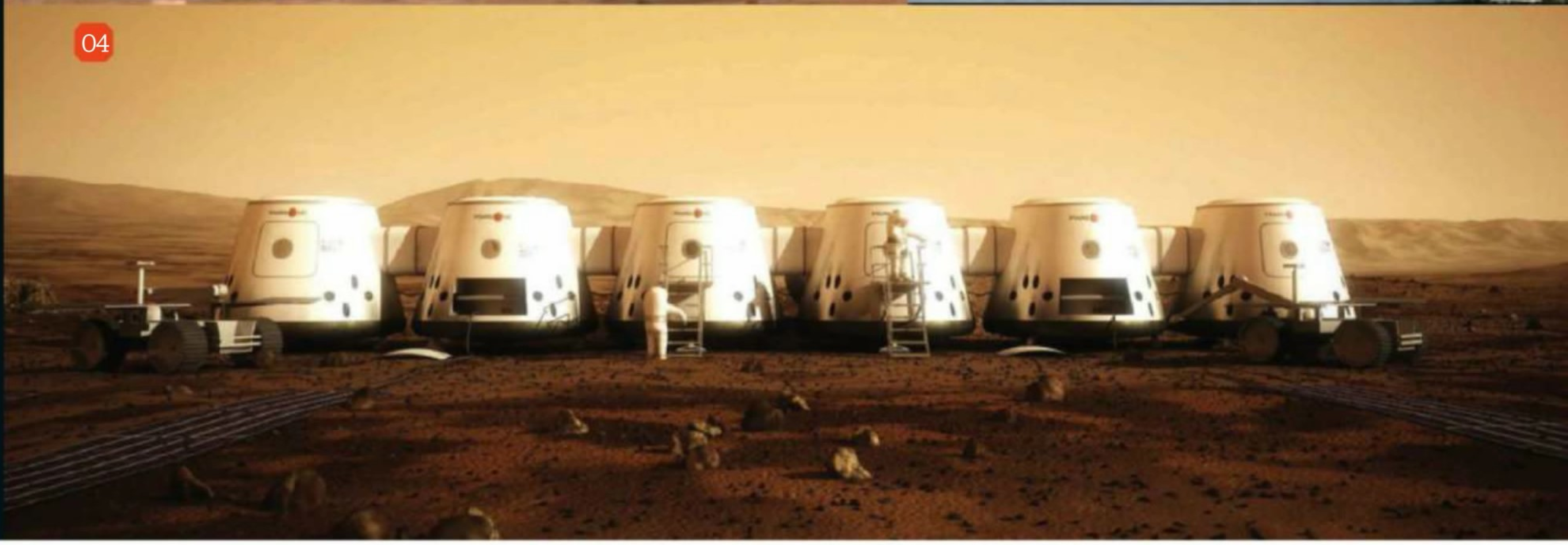

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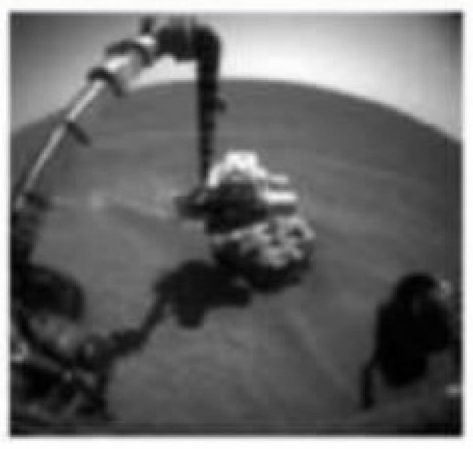
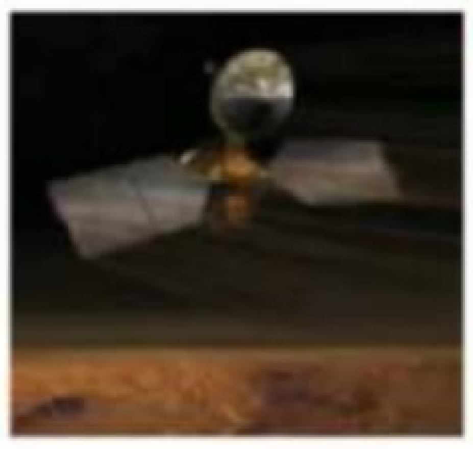


2004
Opportunity

The Opportunity rover has found Martian meteorites, looked into geological processes and studied surface composition.



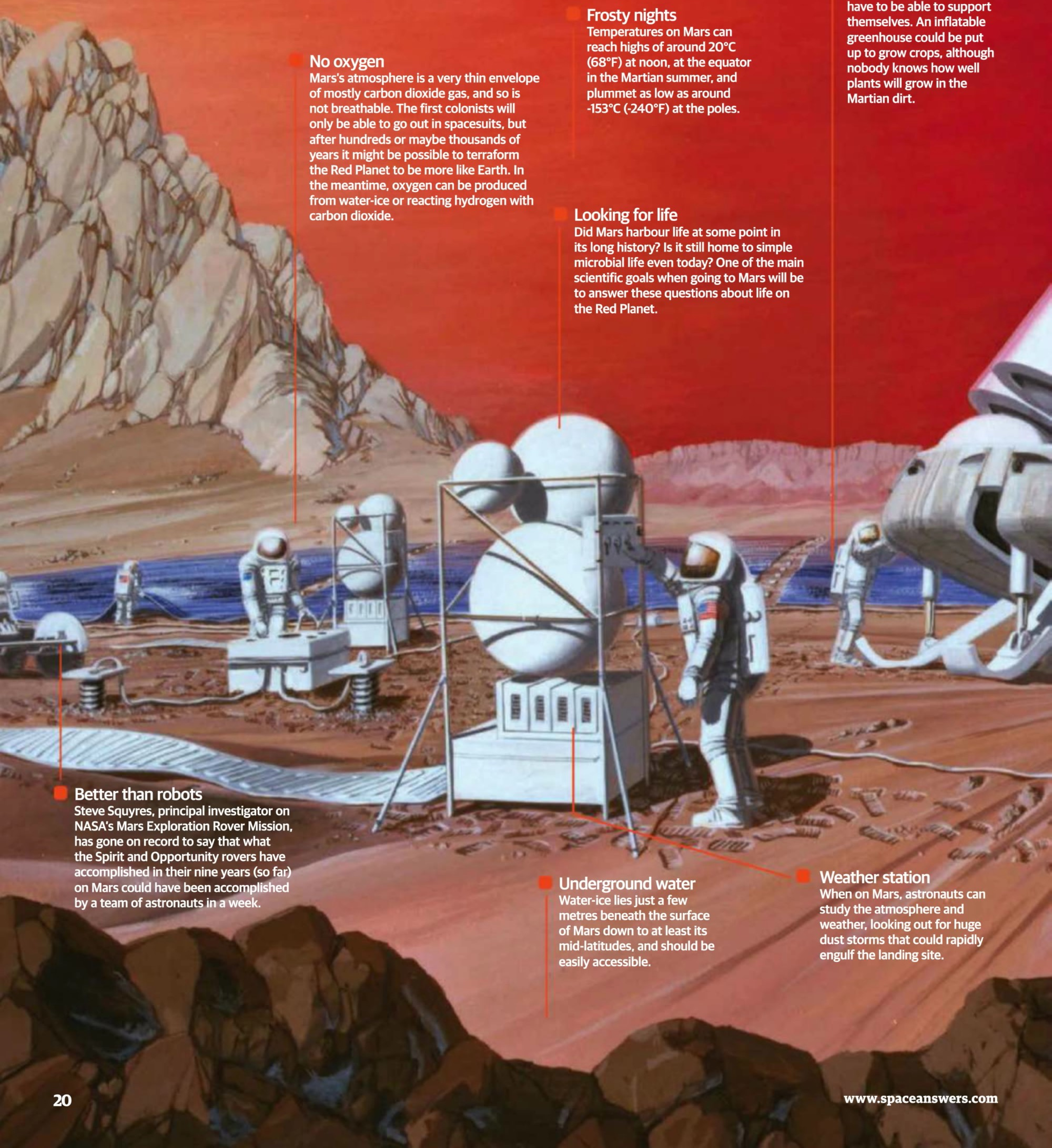
2006
Mars Reconnaissance Orbiter (MRO)

With a suite of instruments, the MRO continues to analyse Mars's weather and surface conditions.

2012
Curiosity

Curiosity is providing information on the past and present habitability of Mars, as well as taking hi-res images of the landscape.

On the surface of Mars



No oxygen

Mars's atmosphere is a very thin envelope of mostly carbon dioxide gas, and so is not breathable. The first colonists will only be able to go out in spacesuits, but after hundreds or maybe thousands of years it might be possible to terraform the Red Planet to be more like Earth. In the meantime, oxygen can be produced from water-ice or reacting hydrogen with carbon dioxide.

Frosty nights

Temperatures on Mars can reach highs of around 20°C (68°F) at noon, at the equator in the Martian summer, and plummet as low as around -153°C (-240°F) at the poles.

A self-supporting colony

Being so far from Earth, Martian explorers will have to be able to support themselves. An inflatable greenhouse could be put up to grow crops, although nobody knows how well plants will grow in the Martian dirt.

Looking for life

Did Mars harbour life at some point in its long history? Is it still home to simple microbial life even today? One of the main scientific goals when going to Mars will be to answer these questions about life on the Red Planet.

Better than robots

Steve Squyres, principal investigator on NASA's Mars Exploration Rover Mission, has gone on record to say that what the Spirit and Opportunity rovers have accomplished in their nine years (so far) on Mars could have been accomplished by a team of astronauts in a week.

Underground water

Water-ice lies just a few metres beneath the surface of Mars down to at least its mid-latitudes, and should be easily accessible.

Weather station

When on Mars, astronauts can study the atmosphere and weather, looking out for huge dust storms that could rapidly engulf the landing site.

Longer days
The length of a Martian solar day, or sol, is 24 hours and 39 minutes. Astronauts will need special Mars watches that factor in this extra 39 minutes.

Landing craft
In Robert Zubrin's Mars Direct mission, he proposed sending habitation modules to Mars with each new crew, eventually building up to the first settlement on the Red Planet.

Geology
The rocks and dirt on Mars can tell us lots about the past climate in their local environment. Some of the first Martian astronauts therefore may well be geologists.

former private astronaut Dennis Tito has launched Inspiration Mars, an organisation that plans to send two humans – a male and female, likely married – on a flyby mission of Mars in 2018. It's a plan that Zubrin himself pitched to NASA in 1995, but they didn't take him up on the idea.

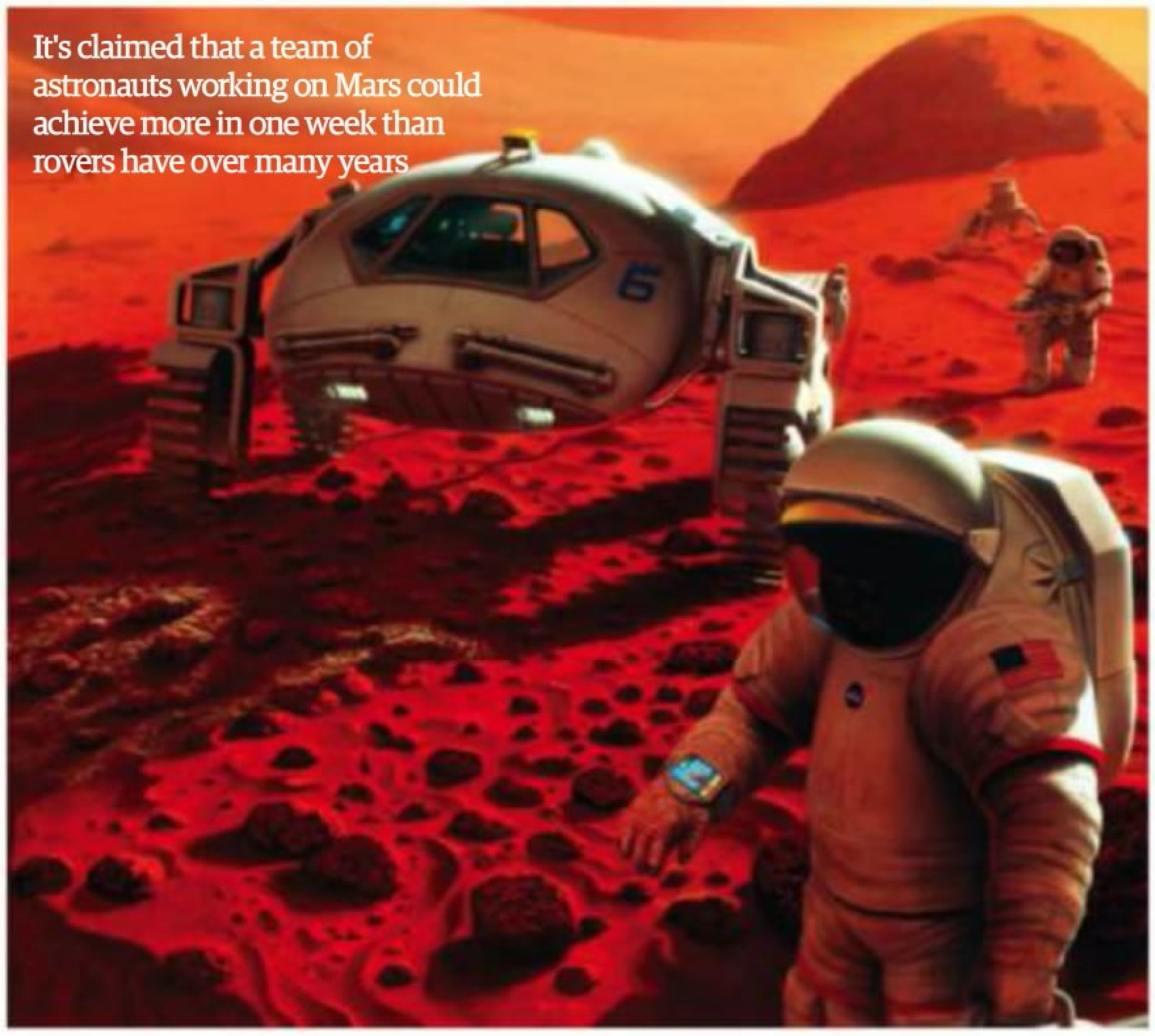
"Really the key question of whether Tito is going to pull this off is whether he can raise the $2 billion needed," says Zubrin. "NASA is funded to a level of $18 billion per year. Now $2 billion is nothing to the government but it is a lot in the private world, but really if NASA had the courage of Tito we would have done this when I proposed it to them in 1995."

Dr Gernot Grömer of the University of Innsbruck and head of the MARS2013 project agrees with Zubrin. "This is a truly ambitious plan," he says. "If you look at their papers where they describe the mission profile, it is well thought through and written by experts who are very good in their subjects. However, for trajectory reasons they have to keep the 2018 deadline." That's the big problem, says Grömer. Dennis Tito is only funding the first three years of that project until the really high financial demand kicks in. Will they then be able to get the financial backing that they need in the time required? "Developing a transportation system which brings people to Mars and back safely is something that will probably take more than the few years left to the 2018 deadline," adds Grömer. "I honestly wish them all the luck, but I am pessimistic that they can really achieve the super-tight schedule."

Another proposed privately funded manned mission is that of Mars One, a not-for-profit organisation based in the Netherlands that intends to establish a permanent human settlement on Mars by 2023, by sending astronauts there on a one-way trip. Their plan is to get funding by turning the adventure into a reality TV show. However, Grömer is less convinced by their plans than he is of Inspiration Mars's.

"Unlike the team of Dennis Tito, the Mars One team lacks the expertise and knowledge how to approach such super-ambitious programmes," he says. "Just simply recruiting and maintaining such a large astronaut corps is well beyond their capabilities, not to speak of launchers, habitats, spacesuits etc. Having big players like SpaceX [behind them] certainly helps, but there is no indication these are doing it for free. That means, that even

> "The basic idea of the Mars Direct mission is to explore Mars with a travel-light philosophy" **Dr Robert Zubrin**


It's claimed that a team of astronauts working on Mars could achieve more in one week than rovers have over many years

"The first human to walk on Mars is already born"

Gernot Grömer, MARS2013 project leader

Currently standing as Europe's largest Mars simulation to date, the month-long 'Mars' expedition dubbed MARS2013, which included field tests of two experimental spacesuits, an astronaut injury scenario, tests of autonomous rovers and a cliff-climbing robot, has now been successfully completed surpassing its very own ambitious objectives. MARS2013 is led by Gernot Grömer, who was previously selected as an astronaut for a simulated Mars expedition in 2003 and 2006 at the Mars Desert Research Station in Utah. Grömer currently serves as a board member of the Austrian Space Forum managing a research programme to develop an advanced spacesuit simulator for human Mars expeditions, and he has participated in a flight team onboard the Airbus A-300 zero-gravity flight programme, where he conducted a series of medical experiments. Grömer's research interests focus on planetology and space exploration both of which he teaches at the University of Innsbruck, Austria.

What did the MARS2013 expedition entail?

Between 1 and 28 February 2013, the Austrian Space Forum - in partnership with the Ibn Battuta Center in Marrakesh - conducted an integrated Mars analog field simulation in the northern Sahara near Erfoud, Morocco in the framework of the PolAres research programme. Directed by a Mission Support Center in Austria, a small field crew conducted experiments preparing for future human Mars missions mainly in the fields of engineering, planetary surface operations, astrobiology, geophysics/geology, life sciences and others. We had a truly international team from 23 countries, involving more than 100 researchers and volunteers, including the United Kingdom.

What did you learn from the MARS2013 expedition?

We had 17 peer-reviewed research experiments and collected a truly large data set which we are now going to analyse in the next 12 months. We are very much looking forward to a science conference in Vienna in May where we will go into the academic discussion.

One of the major outcomes was that we have gained a lot of operational experience in conducting human exploration activities on the surface of another world. This ranges from data on instrument behaviour, biomedical data on the exhaust patterns as well as the efficiency of how to do things such as geoscience in a very efficient manner.

Do you think humans are ready for a trip to Mars?

Yes. It will be the most technically challenging journey our society has ever undertaken, but from the engineering and scientific point of view, we are almost ready. In all our research we haven't encountered a showstopper that told us 'no, you can't go'. This includes hazards such as radiation or human factors but, at the end of the day, I believe we have never been so close to human missions to the Red Planet.

What do you think the future holds for the manned exploration of Mars?

At the Austrian Space Forum we say that the first human to walk on Mars is already born. I personally believe that this generation is the first one to be able to tackle the question of life in the universe on a promising planetary surface for the first time in-situ. If you read a history book in 200 years from now, the economic crisis might only be a marginal chapter, whereas in the long run, our time will be known as the time where we left the planet to discover new worlds.

NASA is preparing for an unmanned test flight of Orion in 2014

"Inspiration Mars is a truly ambitious plan. It is well thought through and written by experts who are very good in their subjects" **Gernot Grömer**

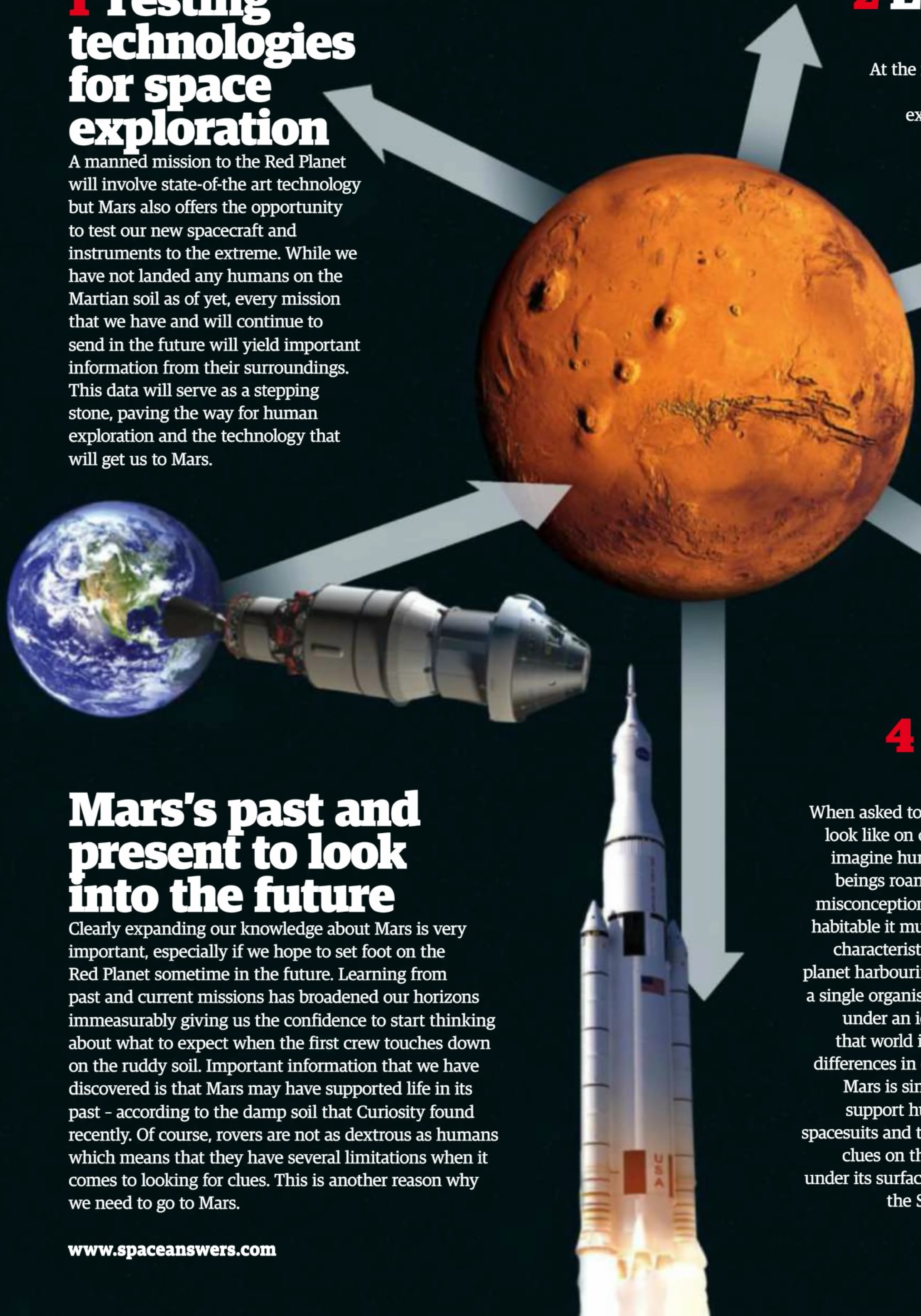
large TV companies won't be able to afford such a multi-year programme, not to mention the challenge of keeping the public interest going for such a long time."

In the meantime, as the various companies look to find the funds to reach the Red Planet, full-blown simulated expeditions to Mars are taking place. For example, isolated for 520 days in a mock-up spacecraft in Moscow, five crewmembers got the full brunt of what it would really be like to be making their way to another planet. The Mars-500 project simulated the Earth to Mars shuttle spacecraft journey, the ascent-descent craft and the Martian surface. Delving deep into the psychological and medical effects that long-distance spaceflight would cause, Mars-500 identified possible problems and solutions that cosmonauts were likely to encounter. Subjected to peculiarities such as a lag in communication between 'Mars' and 'Earth', rationing of food and having to live in an enclosed space with others for a long period of time, these Martian explorers were tested to their limits. While several crewmembers experienced problems sleeping, avoided exercise to counteract the effects of space travel and would hide away from

Studying the Martian landscape will provide us with clues as to whether it was once habitable

5 reasons we need to go to Mars

Why getting mankind to the Red Planet is so important



1 Testing technologies for space exploration

A manned mission to the Red Planet will involve state-of-the art technology but Mars also offers the opportunity to test our new spacecraft and instruments to the extreme. While we have not landed any humans on the Martian soil as of yet, every mission that we have and will continue to send in the future will yield important information from their surroundings. This data will serve as a stepping stone, paving the way for human exploration and the technology that will get us to Mars.

2 Establishing human life elsewhere

At the moment, the only planet that we know of that harbours any complex life is Earth. But what if we humans could exist elsewhere? Mars has the potential, despite its hostile environment, to offer colonisation as an option.

3 Conquering frontiers

Despite being the closest planet to us which bears some similarities to Earth, experts have not let the fact that a manned mission to Mars would be difficult escape their notice. However, for the first time in history, a species on Earth has the knowledge and technology to make the journey to another planet possible. Making the journey to Mars and landing on its

of a lifetime.

4 Looking for life

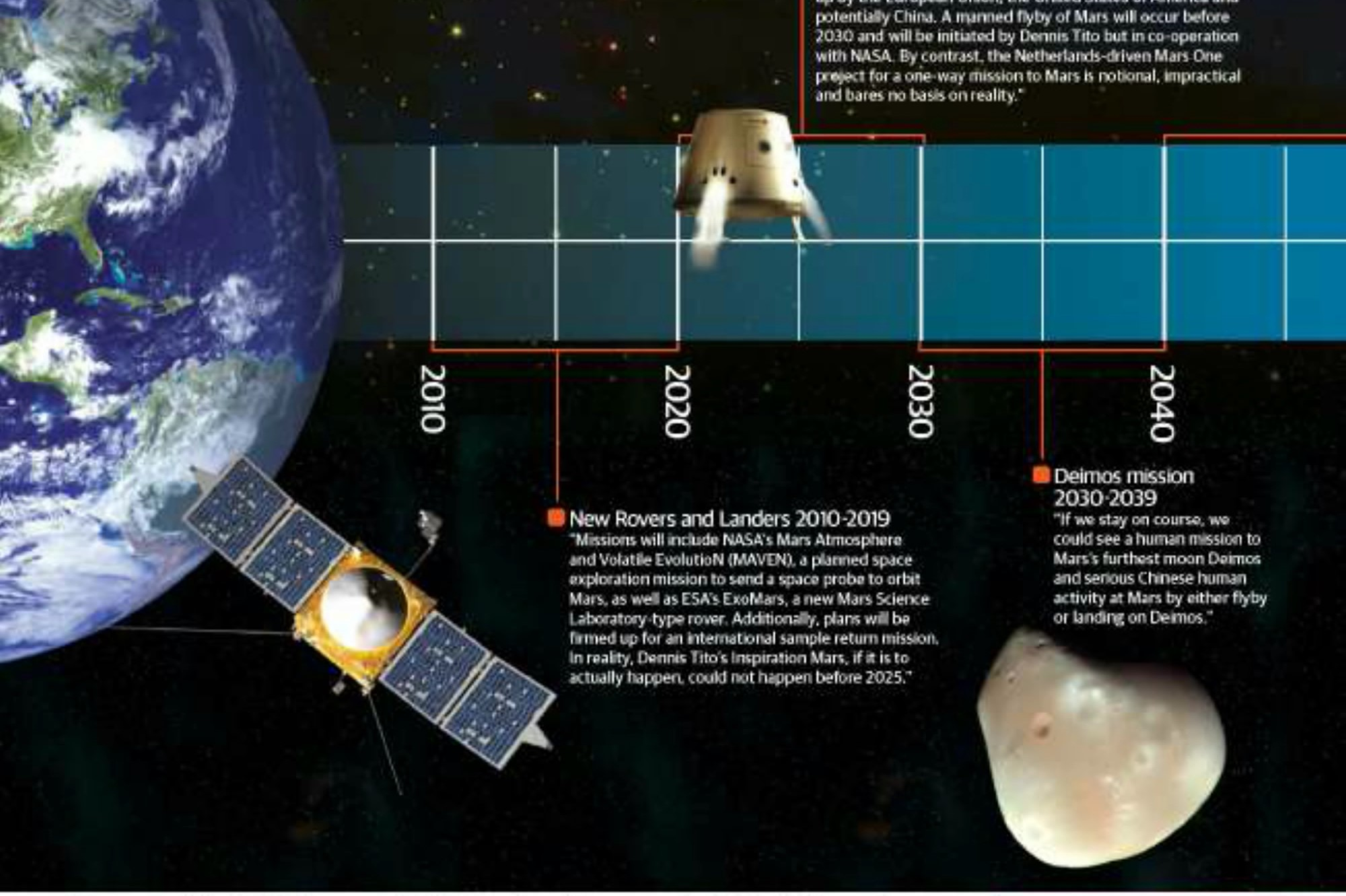
When asked to envision what life might look like on other planets, it is easy to imagine humans or even sub-human beings roaming their world. Another misconception is that for a planet to be habitable it must have exactly the same characteristics as our Earth. A frozen planet harbouring something as small as a single organism surviving comfortably under an icy planetary crust means that world is habitable no matter the differences in comparison to our home. Mars is similar, while it is unable to support humans without the aid of spacesuits and technology, it can provide clues on the conditions for life both under its surface and on other planets in the Solar System and beyond.

Mars's past and present to look into the future

Clearly expanding our knowledge about Mars is very important, especially if we hope to set foot on the Red Planet sometime in the future. Learning from past and current missions has broadened our horizons immeasurably giving us the confidence to start thinking about what to expect when the first crew touches down on the ruddy soil. Important information that we have discovered is that Mars may have supported life in its past - according to the damp soil that Curiosity found recently. Of course, rovers are not as dextrous as humans which means that they have several limitations when it comes to looking for clues. This is another reason why we need to go to Mars.

Road map to Mars

Author of *Mars: A Cosmic Stepping Stone*, Kevin Nolan speculates on how he thinks Mars exploration will develop in the next seven decades



First manned fly-by 2020-2029
"A European Union-driven sample return mission by around 2025. Human astronaut programme for Mars will be ramped up by the European Union, the United States of America and potentially China. A manned flyby of Mars will occur before 2030 and will be initiated by Dennis Tito but in co-operation with NASA. By contrast, the Netherlands-driven Mars One project for a one-way mission to Mars is notional, impractical and bares no basis on reality."

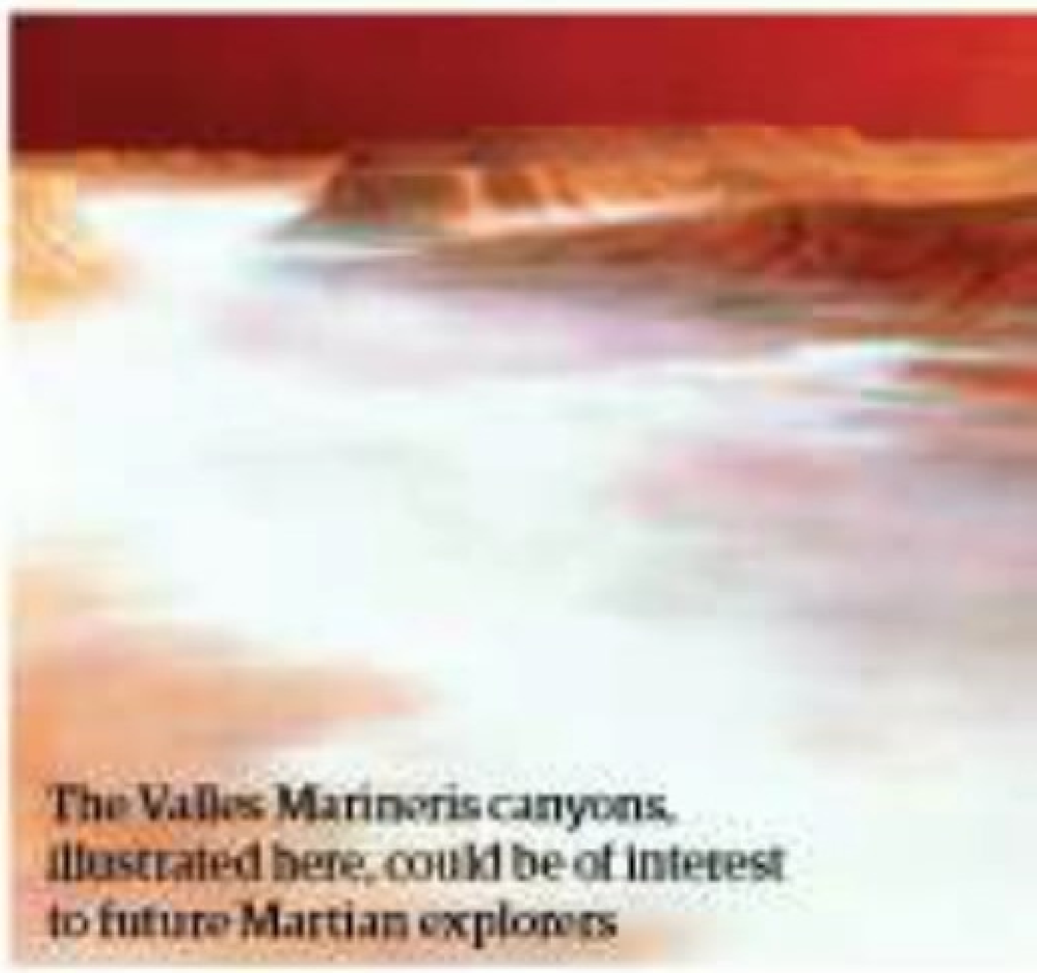
New Rovers and Landers 2010-2019
"Missions will include NASA's Mars Atmosphere and Volatile EvolutioN (MAVEN), a planned space exploration mission to send a space probe to orbit Mars, as well as ESA's ExoMars, a new Mars Science Laboratory-type rover. Additionally, plans will be firmed up for an international sample return mission. In reality, Dennis Tito's Inspiration Mars, if it is to actually happen, could not happen before 2025."

Deimos mission 2030-2039
"If we stay on course, we could see a human mission to Mars's furthest moon Deimos and serious Chinese human activity at Mars by either flyby or landing on Deimos."

their crewmates, Mars-500, which ran between 2007 and 2011 and admitted three separate crews, proved a success, with most volunteers reportedly being in good physical and psychological condition. However, with simulated missions to the Red Planet far from over, experts want to put potential astronauts to the test even more. How would they deal with completing actual scientific experiments and walking for miles across the tough Martian terrain?

For such an occasion there was the aforementioned MARS2013 project, which took place in February 2013. The month-long simulation was initially based at Camp Weyprecht in the Mars-like Moroccan desert, before a three-day excursion collecting rock samples on the way to a second 'landing site' called Station Payer that had been established by four of the ten-member team of analog astronauts. Led by Gernot Grömer, MARS2013 was the biggest Mars simulation ever performed by a European organisation,

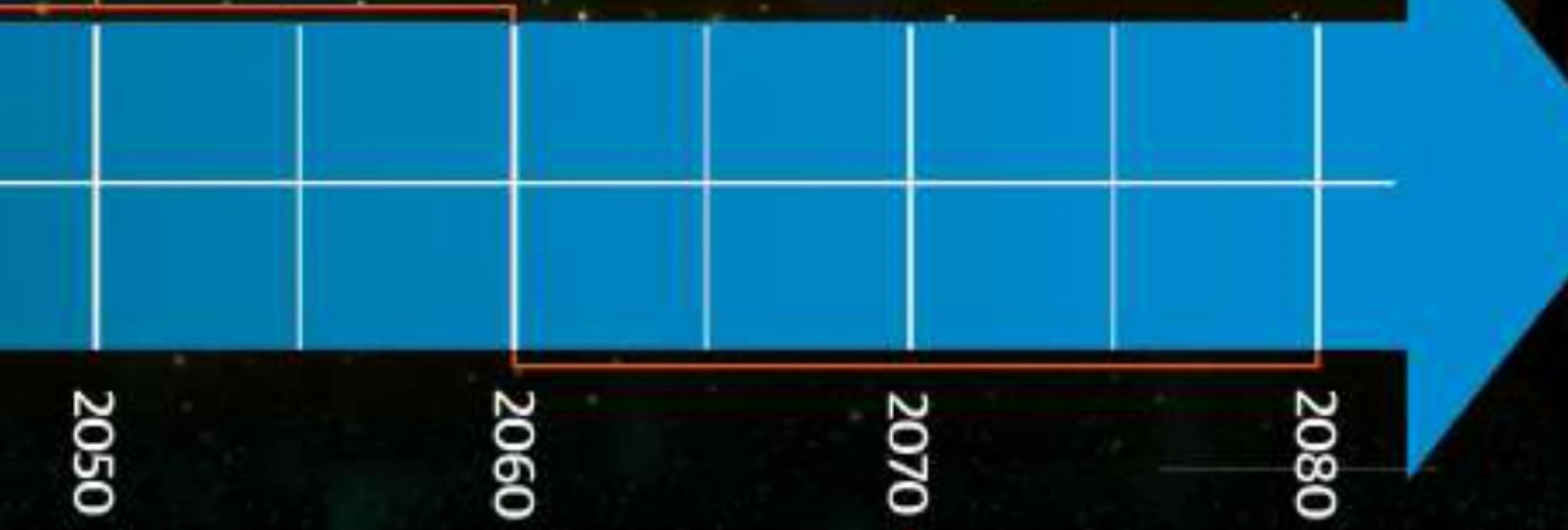
> "The Mars One team lacks the expertise and knowledge how to approach such super-ambitious programmes" **Dr Gernot Grömer**



The Valles Marineris canyons, illustrated here, could be of interest to future Martian explorers

500 day stay 2040-2059

"If we're to set people on the surface of Mars then it most likely cannot happen before 2040 (with current forecasts). The notion of placing people on the surface (for a required 500-day stay there) would need significant resources, such as supply missions two years in advance, landing mining nuclear power stations on the surface, return fuel in-situ manufacturing facility. All of these are decades away, so a 20-year interval time period is most likely for actual human missions to land on the surface of Mars."



Long term prescence 2060-2079

"When you consider we've been in space for over 50 years and what we've done in that time, one can sense the lengths of time needed, the commitment by countries and governments and the readiness of people. These issues, coupled with the extraordinary technology and budgets required, pushes a long-term human presence on Mars well into the second half of this century in my opinion. An en masse migration of people to the surface of Mars will be another entire agenda well into the next century. Of course, these are speculations, and one multibillionaire could propel all of this forward by decades!"

involving 23 nations and more than 100 scientists. The team performed 17 scientific experiments, as well as field-testing new spacesuit designs and deployable shelters, acting out an astronaut-injury situation and testing cliff-climbing robots. Like Mars-500, a 20-minute 'time delay' was included in all communications with 'Earth', simulating the wait as radio waves travel at the speed of light from Mars to Earth and then back again. Data collected from such simulations is important in planning and preparing for the real thing.

And when is that 'real thing' likely to occur? The Mars enthusiasts at Inspiration Mars, Mars One, the Mars Society and SpaceX would argue that it could happen by the end of the current decade, or the beginning of next. Others, however, are playing it safer, and suggesting 2030 or later as the most likely date for mankind to reach the Red Planet. In the end it will be decided by who can raise the necessary money and have the courage that Zubrin says is essential to make history by being the first to send people to Mars. ●

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The Giant Nebula

This intense starburst region contains some of the biggest stars known to mankind

NGC 3603, also known as the Giant Nebula, is one of the most massive young star clusters in the Milky Way Galaxy. It is located approximately 20,000 light years from Earth in the Carina constellation and is surrounded by the material needed for the birth of new stars, namely interstellar dust and gas.

Inside the Giant Nebula are a huge number of different stars, ranging from small to massive and hot to relatively cool. Such is the diversity of stars in this nebula that it contains some of the largest stars that we currently know of, including NGC 3603-A1, a fascinating binary star system composed of two stars that are 116 and 89 times the mass of our Sun. These are currently the most massive stars we've found whose masses have been directly measured and not estimated.

The relative proximity of the Giant Nebula makes it especially interesting for astronomers. Its active star formation helps provide clues about the birth of stars in the early universe, and also how new stars form in colliding galaxies.

In addition, unusually strong ultraviolet radiation and stellar winds have blown away the dust and gas that would usually reside at the heart of such a nebula, providing us with an unobscured view of this fascinating region.

© NASA

5 AMAZING FACTS ABOUT

Project Mercury

Mercury was narrowly beaten by Vostok

Three weeks before Yuri Gagarin became the first human in space, NASA flew a successful unmanned Mercury flight. But it could have been a manned flight. NASA was overly cautious, and Shepard eventually flew into space three weeks after Gagarin.

It nearly drowned Gus Grissom

When Gus Grissom splashed down in the Atlantic Ocean on 21 July 1961 on the second Project Mercury flight, the explosive bolts on his hatch accidentally fired. Grissom scrambled out into the water before the spacecraft sank (it was recovered 38 years later), barely staying afloat until he was rescued.

20 Mercury spacecraft were built

NASA selected the McDonnell Aircraft company to build 20 separate Mercury spacecraft. Of these, six were used for manned flights (a seventh flight was cancelled), nine were used for unmanned flights (two of which were destroyed) and five never flew.

The first Mercury 'pilot' was a monkey

On 4 December 1959, a rhesus monkey called Sam became the first 'astronaut' in the Mercury programme. He flew to a height of 85 kilometres (53 miles) – 15 kilometres (nine miles) short of space – on a prototype spacecraft called Little Joe 2.

The astronauts insisted on having a window

Early prototype Mercury spacecraft had just two portholes, but the Mercury astronauts demanded that a larger window be installed, not only for the view but also for orientation. The latter proved invaluable on the last mission, when instrument failure required visual orientation.

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Boats on Titan

NASA and ESA are looking at ways to sail the seas of Saturn's largest moon

The Titan Mare Explorer (TiME) and Titan Lake In-situ Sampling Propelled Explorer (TALISE) are two missions currently being proposed to explore Saturn's fascinating moon Titan. NASA is considering the first as part of its high-profile Discovery Programme, while TALISE (which also translates as 'beautiful water' in Native American) is a European proposal. Both would be designed to probe the surface of Titan in much the same way rovers have scoured Mars, save for one key difference: they would travel by sea rather than land.

Titan, first discovered by Dutch astronomer Christiaan Huygens on 25 March 1655 using a homemade telescope, is the largest moon of Saturn and is thought to be one of the few places in the Solar System other than Earth where life has a potential to survive in some shape or form. It was the subject of NASA and ESA's Cassini-Huygens mission that carried out multiple flybys before dropping the Huygens probe on its surface on 14 January 2005, which returned valuable data and even images of the surface that piqued the interest of scientists worldwide. Now, the agencies want to go back with bigger and better equipment. The destination for both could be Ligeia Mare, the second-largest body of liquid on Titan at around 100,000 square kilometres (39,000 square miles).

TiME was originally in competition with two other NASA Discovery missions for funding in 2016 but, ultimately, it lost out to a low-risk Mars mission called InSight. However, it will remain in consideration for a future mission, perhaps in tandem with an orbiting spacecraft to enable communications with Earth even when our planet dips below Titan's horizon (and therefore out of view) in the 2030s. TALISE, meanwhile, is in the concept phase, with a possible launch date yet to be discussed.

To become humanity's first 'boats' on another world, TiME and TALISE will be designed to survive and study the harsh methane-ethane sea on Saturn's moon. Both would have a mass spectrometer that will be used to find the chemical composition of the sea, while meteorology and physical properties packages will determine the liquid depth and characterise the atmosphere above. Cameras will also image the surface of the sea, which is thought to be relatively calm with waves no higher than half a metre, and the surrounding area.

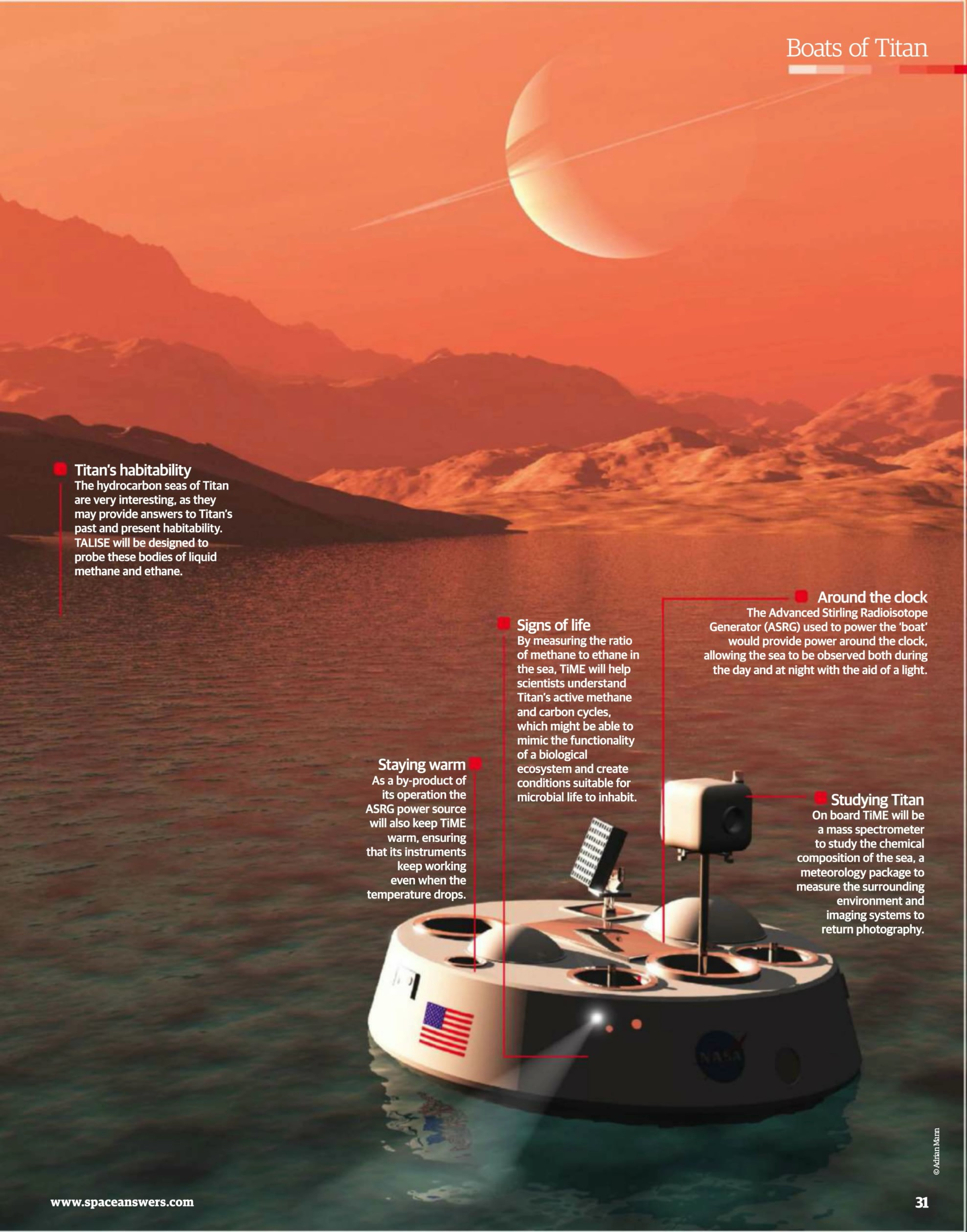
Once it has splashed down, TiME would operate for about 96 days, returning data to ground control on Earth. To save on cost and weight, it will not have its own form of propulsion. Instead, it will drift solely on the wind and waves, exploring the surrounding liquid as it moves. This is where TiME and TALISE differ. As the latter's name suggests, it would have a means to propel itself in a body of liquid on Titan's surface. This would be in the form of propellers on the side of the probe shaped as wheels, paddles or screws. After landing, TALISE would make its way to the coast over a period of six months to a year. Therefore, not only would TALISE be able to collect liquid samples from the sea, but it might also be able to collect solid samples from the shoreline.

It remains to be seen if either of the proposals are selected for a future mission, but there's little doubt that the science that could be gained from either one would be astounding.

Sailing the seas
Several methods of propulsion were considered for TALISE, including hovercraft-esque capabilities and liquid propellers, but eventually it was decided that paddles in the shape of wheels, screws or crosses would be best.

Nuclear power
It's as yet undecided how TALISE would be powered, but nuclear power would be an option. Solar power would not, as the Sun's light is too dim on Titan, while suggestions of using the methane on Titan as a power source are untested.

Collecting samples
On board TALISE would be a magnetometer to measure the environment and cameras to image its surroundings, in addition to many other instruments that will allow the vehicle to study Titan's seas and collect samples.



Titan's habitability
The hydrocarbon seas of Titan are very interesting, as they may provide answers to Titan's past and present habitability. TALISE will be designed to probe these bodies of liquid methane and ethane.

Around the clock
The Advanced Stirling Radioisotope Generator (ASRG) used to power the 'boat' would provide power around the clock, allowing the sea to be observed both during the day and at night with the aid of a light.

Signs of life
By measuring the ratio of methane to ethane in the sea, TiME will help scientists understand Titan's active methane and carbon cycles, which might be able to mimic the functionality of a biological ecosystem and create conditions suitable for microbial life to inhabit.

Staying warm
As a by-product of its operation the ASRG power source will also keep TiME warm, ensuring that its instruments keep working even when the temperature drops.

Studying Titan
On board TiME will be a mass spectrometer to study the chemical composition of the sea, a meteorology package to measure the surrounding environment and imaging systems to return photography.

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JOURNEY THROUGH THE MILKY WAY

Written by Giles Sparrow

Our home in the universe is a giant spiral system containing many billions of stars - but how much do we really know about it, and what do we still have to learn?

Look up at the sky on a dark, clear night and you can't miss the Milky Way – a broad swathe of pale light winding its way around the sky among many of the brightest individual stars. Ancient astronomers saw it as a stream of milk spilt across the sky by the goddess Hera when she suckled the hero Hercules, but today we know the Milky Way is something very different – an enormous disc of stars some 100,000 light years across, containing (at the latest estimate) around 200 billion individual stars.

Unsurprisingly, then, our Solar System is an insignificant speck within the overall scale of the Milky Way – all the planets and other large bodies orbiting the Sun are confined to a region just a few light *hours* across. In our part of the galaxy, stars are spaced far enough apart that even our nearest stellar neighbours appear as mere specks of light. The closest of all, the triple star Alpha Centauri, is still around 4.3 light years away.

The overall shape of our galaxy has been likened to two fried eggs placed back to back, with a broad, flat disc of scattered stars, gas and dust surrounding a bulging central hub where stars are more densely packed together. Our Solar System and its neighbours lie in a relatively sedate, outlying region of the Milky Way, about halfway between the centre and the edge. With a little understanding of the Milky Way's structure, the band of light across the night sky is easy to understand: when we look across the plane of the Milky Way's disc, we see far more stars lying in any given direction and these effectively merge together into a generalised glow. On the other hand, when we look 'up' or 'down', out of the galactic plane, we are staring into largely empty intergalactic space, with only relatively nearby stars in our part of the disc to get in the way.

In 1785, astronomer William Herschel made the first attempt to map the Milky Way in detail, by exhaustively counting the number of stars he could see in different directions across the sky. He proved beyond doubt that the Milky Way was a flattened plane, but unfortunately misunderstood its shape because he believed that our own Solar System was near the centre of the galaxy.

In the late-Twenties, Jan Oort set out to study the movement of individual stars in different parts of the sky. He soon confirmed that the Milky Way is rotating, showed that its centre lies in the direction of the constellation Sagittarius, and also proved that galaxies do not rotate like solid bodies – instead the stars closer to the galactic hub move more quickly along their orbits, while stars further out circle more slowly – a phenomenon known as 'differential rotation'. The Sun, for instance, takes around 200 million years to complete a single orbit. Later measurements in different parts of the disc showed that orbital speeds do not change as dramatically as

> "The most brilliant stars don't survive long enough for their orbits to carry them out of the spiral arms"

they should do if they are governed by the mass of the Milky Way's visible matter alone - evidence that our galaxy contains large amounts of transparent but weighty 'dark matter'.

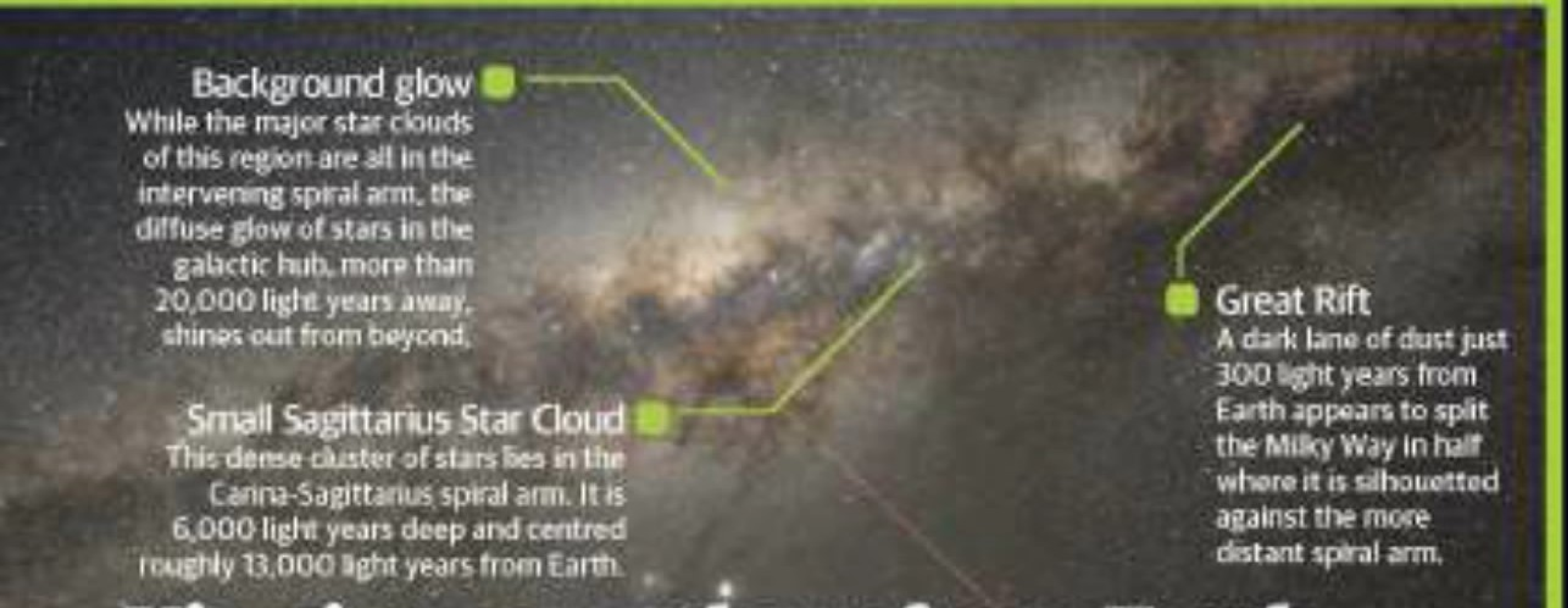
Even today, our understanding of our galaxy is constantly evolving thanks to new theories and new observing technologies. Radio, infrared, ultraviolet and X-ray observations can pierce the dense clouds of stars and dust that obscure large parts of the Milky Way in visible light, while new analytical techniques allow astronomers to learn far more from the stars we can observe. So what is our current understanding of this enormous stellar system?

The Milky Way is a barred spiral galaxy, around 100,000 light years across and with a disc roughly 1,000 light years thick in most places. Its central hub is formed by a densely packed ball of stars roughly 8,000 light years in diameter, out of which a bar of stars some 27,000 light years long emerges. The bar points more or less directly towards our Solar System, and as a result its existence was uncertain until it was finally confirmed by NASA's infrared Spitzer Space Telescope in 2005.

Two major spiral arms emerge from the ends of this bar. Until recently, our galaxy was thought to have four major arms, but further observations have led to two of them being 'downgraded'. The two survivors are known as the Scutum-Centaurus Arm and the Perseus Arm. They alternate with the two recently demoted arms - the Sagittarius and Norma arms. The picture is complicated by numerous other disconnected regions that follow the general sweep of the spiral arms. For instance, our own Solar System lies on the inside edge of a 10,000 light year fork in the Sagittarius Arm, known as 'Orion Spur', while both the Sagittarius and Norma arms are thought to trail off into disconnected clumps that wrap their way around the galaxy's outer perimeter. The outer extension of the Norma Arm, which lies on our side of the galactic centre and is therefore more easily seen, is known as the Outer Arm.

The Milky Way's spiral arms are not permanent, linked structures - otherwise the differential rotation discovered by Jan Oort would cause them to 'wind up' after just a few rotations. Instead, they perpetually renew themselves. In fact, the arms seem to be celestial traffic jams, created where stars and gas in circular orbits around the galactic hub enter a spiral 'density wave' region where they are slowed down and jammed together. This triggers the creation of new star-forming nebulas that light up the spiral arms with the pinkish glow of hydrogen emission, and ultimately give birth to 'open clusters' of stars.

However, these stellar foundries are short-lived on a galactic timescale - they exhaust their supplies of star-forming gas within a few million years, and the heaviest stars squander their fuel in a few million more. As a result, the most brilliant stars don't survive long enough for their orbits to carry them out of the spiral arms - instead it's the more sedate, longer-lived stars like our own Sun that make it out of the traffic jam to continue their orbits around the galactic disc over billions of years.



Background glow
While the major star clouds of this region are all in the intervening spiral arm, the diffuse glow of stars in the galactic hub, more than 20,000 light years away, shines out from beyond.

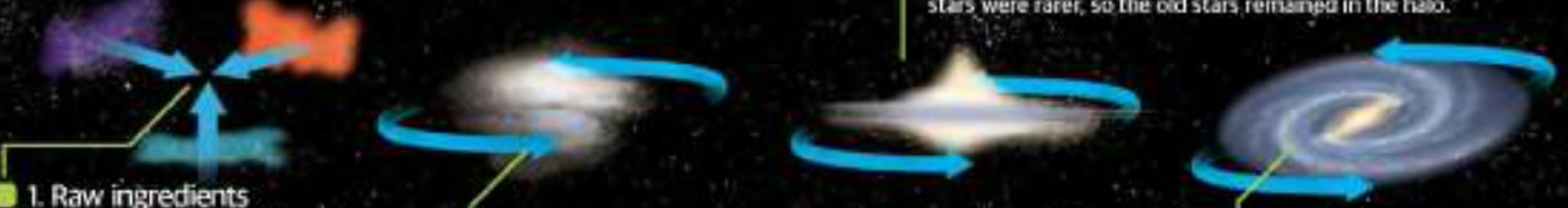
Small Sagittarius Star Cloud
This dense cluster of stars lies in the Carina-Sagittarius spiral arm. It is 6,000 light years deep and centred roughly 13,000 light years from Earth.

Great Rift
A dark lane of dust just 300 light years from Earth appears to split the Milky Way in half where it is silhouetted against the more distant spiral arm.

Viewing our galaxy from Earth

As early as the 18th Century, astronomers realised that the winding path of the Milky Way across the sky is a result of our location in a broad, relatively flat plane of stars. But our Solar System's location sandwiched between the major spiral arms complicates the picture considerably, so that different arms in different parts of the sky run together and overlap in places to form a seamless river of light. The picture is further complicated by the presence of dark dust lanes that obscure the light of more distant star clouds: perhaps the most famous of these is the Great Rift, which runs through the constellations of Cygnus and Aquila. The brightest and broadest part of the Milky Way, meanwhile, lies in the direction of Sagittarius and Scorpius. It consists largely of the Carina-Sagittarius Arm and marks the direction of the hub and galactic centre. On the opposite side of the sky, meanwhile, the Perseus Arm runs around the outer edge of the galaxy as seen from our point of view.

Birth of the Milky Way



1. Raw ingredients
The Milky Way is thought to have originated from the coming together of a number of smaller irregular clouds of stars as well as gas and dust within a couple of billion years of the Big Bang in which the universe itself was born.

2. Giant star cloud
Initially, the combined cloud would have had a slow rotation in a more or less random direction. As it collapsed inwards under its own gravity, it gradually began to spin more rapidly.

3. Flattening out
Clouds of gas and dust in random orbits would have tended to collide and merge, cancelling out their random motions until they were concentrated in a single plane. Collisions between more widely spaced stars were rarer, so the old stars remained in the halo.

4. Dominant disc
As the galaxy evolved, new stars formed only in the disc and hub regions, leaving the halo as an ancient remnant of the galaxy's earliest stars.

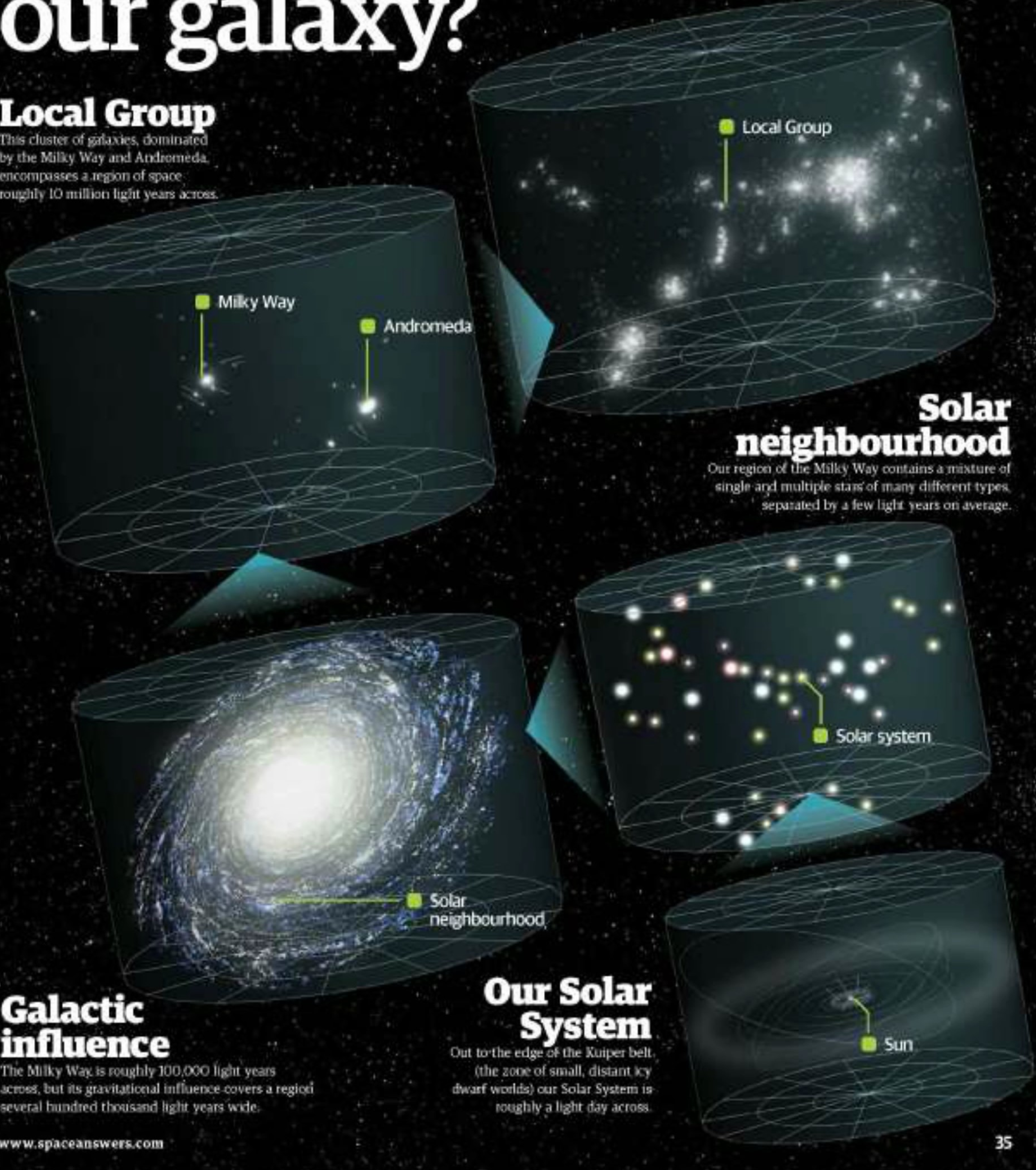
Where is our galaxy?

Virgo Supercluster

The Local Group lies on the outskirts of a galaxy supercluster centred around the Virgo Cluster, some 60 million light years away.

Local Group

This cluster of galaxies, dominated by the Milky Way and Andromeda, encompasses a region of space roughly 10 million light years across.



Solar neighbourhood

Our region of the Milky Way contains a mixture of single and multiple stars of many different types, separated by a few light years on average.

Galactic influence

The Milky Way is roughly 100,000 light years across, but its gravitational influence covers a region several hundred thousand light years wide.

Our Solar System

Out to the edge of the Kuiper belt (the zone of small, distant icy dwarf worlds) our Solar System is roughly a light day across.

At the inner limit of the spiral arms, the bar and hub are surrounded by a structure known as the 5-kiloparsec Ring (one kiloparsec is around 3,260 light years). Although we cannot see it in visible light, the ring seems to contain huge concentrations of star-forming nebulas and young stars: it's probably the main generator of new stars in the Milky Way.

Above and below the main disc lies a relatively empty region known as the halo. Many faint, long-lived stars pass through this region on tilted orbits, but the halo's most obvious occupants are globular clusters - dense balls containing many tens of thousands of old, red and yellow stars that are generally found above and below the galactic hub. Similar red and yellow stars dominate the hub and bar - they are relatively poor in heavy elements, which allows them to shine for billions of years without evolving significantly. As a result, they are known as 'Population II' stars, in contrast to the younger, faster-evolving and heavy-element-enriched 'Population I' stars in the galactic disc.

Among all these stars, the huge majority are low-mass red and orange dwarfs - stars with a fraction of the mass of the Sun, which shine so faintly that they can only be seen when they are relatively nearby. Brighter and more massive stars are much rarer, but tend to shine out over huge distances and so appear more prominently in our skies. Similarly, ageing but brilliant red and orange giants are common among the naked-eye stars seen from Earth, but in fact far rarer than they might appear at first glance.

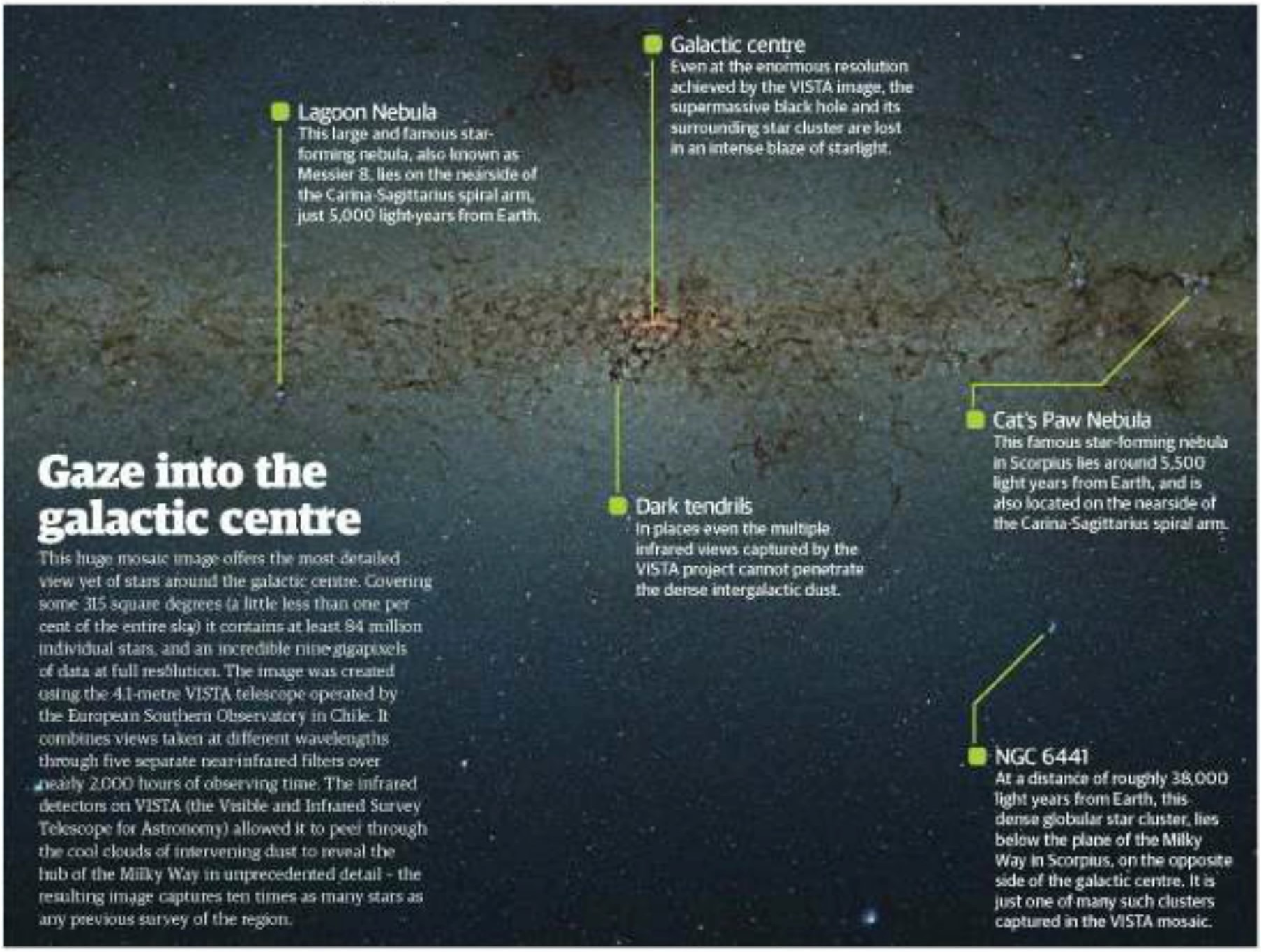
What's more, stars in our galaxy seem to be gregarious - although they gradually drift apart from the open clusters in which they form, many stars remain together in binary or multiple star systems. Recent research also suggests that planetary systems are also common - there may be at least as many planets as there are stars in the sky.

Within the hub, stars become more densely packed towards the centre of the Milky Way - the galactic core. Only X-rays, radio waves and some infrared waves can pass through these dense star clouds unaffected, but they reveal an intriguing picture of the strange and violent conditions in the core itself.

At radio wavelengths, the core is marked by a complex radio source known as Sagittarius A - it consists of a bubble-like structure (Sagittarius A West) a few tens of light years across - probably the remnant of an enormous supernova explosion. Embedded within this is a three-armed spiral called Sagittarius A East, roughly ten light years across. The middle of the spiral coincides with the densest concentration of stars in the Milky Way, and a third, point-like source of radio waves known as Sagittarius A* that is believed to mark the Milky Way's centre.

X-ray emissions reveal huge bubbles and twisted lobes of superhot gas across the region - a mix of supernova remnants and the effects of hot stellar

> "The Milky Way is a major component of the Local Group - a small galaxy cluster some 10 million light years across"



Gaze into the galactic centre

This huge mosaic image offers the most detailed view yet of stars around the galactic centre. Covering some 315 square degrees (a little less than one per cent of the entire sky) it contains at least 84 million individual stars, and an incredible nine gigapixels of data at full resolution. The image was created using the 4.1-metre VISTA telescope operated by the European Southern Observatory in Chile. It combines views taken at different wavelengths through five separate near-infrared filters over nearly 2,000 hours of observing time. The infrared detectors on VISTA (the Visible and Infrared Survey Telescope for Astronomy) allowed it to peer through the cool clouds of intervening dust to reveal the hub of the Milky Way in unprecedented detail - the resulting image captures ten times as many stars as any previous survey of the region.

Lagoon Nebula
This large and famous star-forming nebula, also known as Messier 8, lies on the nearside of the Carina-Sagittarius spiral arm, just 5,000 light-years from Earth.

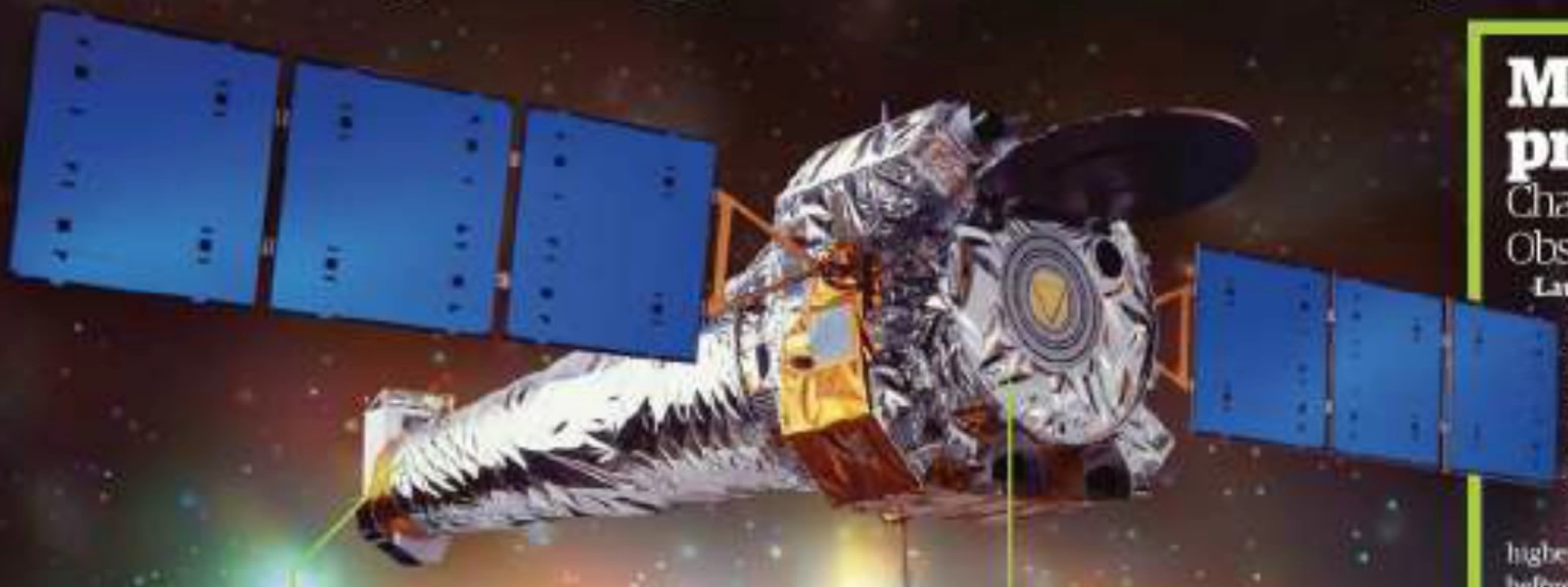
Galactic centre
Even at the enormous resolution achieved by the VISTA image, the supermassive black hole and its surrounding star cluster are lost in an intense blaze of starlight.

Dark tendrils
In places even the multiple infrared views captured by the VISTA project cannot penetrate the dense intergalactic dust.

Cat's Paw Nebula
This famous star-forming nebula in Scorpius lies around 5,500 light years from Earth, and is also located on the nearside of the Carina-Sagittarius spiral arm.

NGC 6441
At a distance of roughly 38,000 light years from Earth, this dense globular star cluster, lies below the plane of the Milky Way in Scorpius, on the opposite side of the galactic centre. It is just one of many such clusters captured in the VISTA mosaic.

Studying the Milky Way



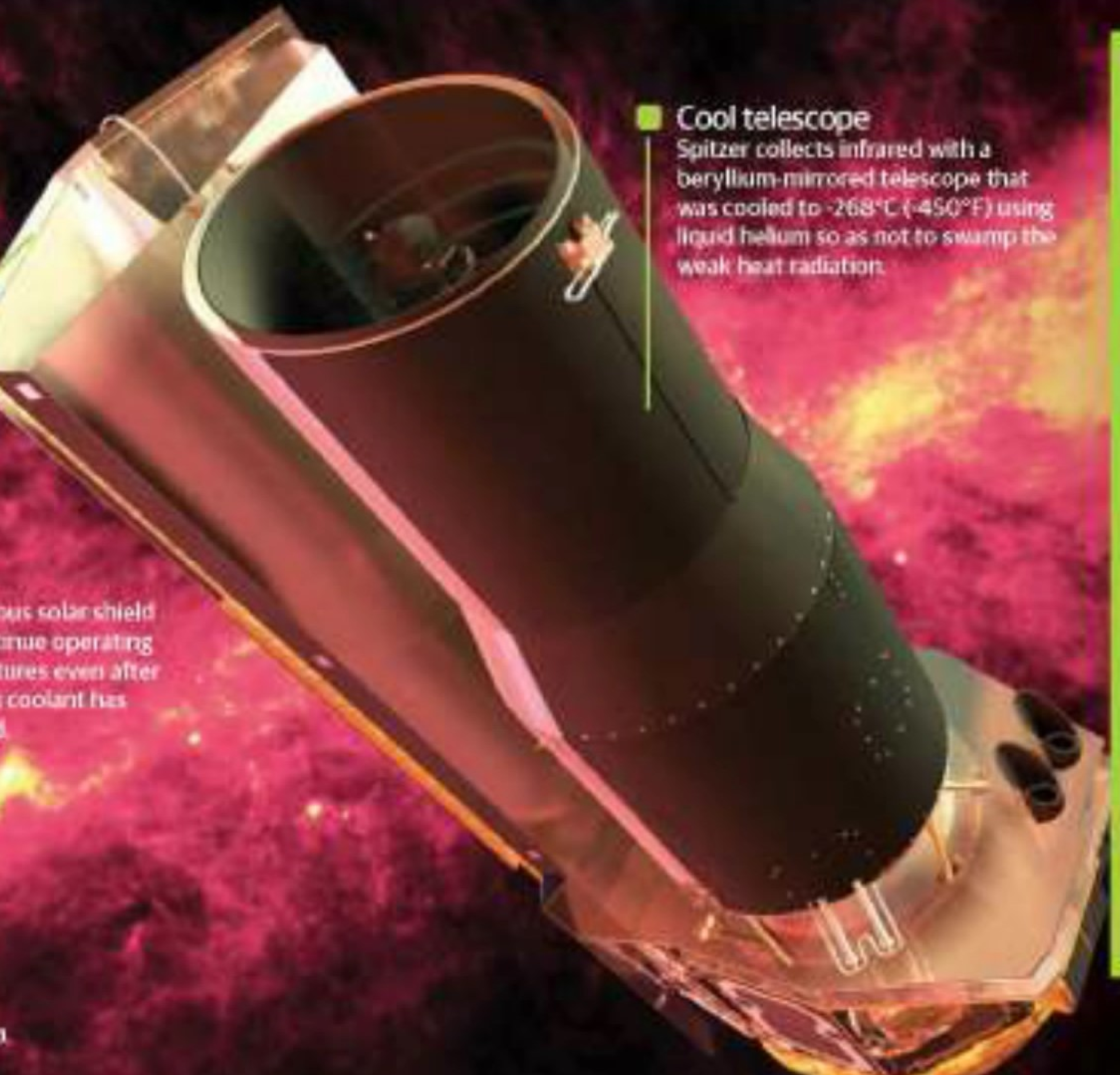
Detector instruments
Two different instruments – the High-Resolution Camera and the Advanced CCD Imaging Spectrometer – can record images from the X-rays or detect their different energy levels.

Mirror assembly
Powerful X-rays pass straight through normal mirrors, so Chandra uses a series of nested metal cones at shallow angles, which ensure the X-rays ricochet to a focus.

Mission profile

Chandra X-ray Observatory

Launch date: 23 July 1999
Launch vehicle: Space Shuttle Columbia
Mass: 4,790kg
Telescope diameter: 1.2m
Mission: Chandra was designed to image the high-energy X-ray sky at higher resolutions than ever before, detecting phenomena such as hot interstellar and intergalactic gas clouds, black holes and other stellar remnants.
Key discoveries: Chandra has allowed the region around Sagittarius A* to be imaged in detail, while the X-ray echoes it has detected have shown that the supermassive black hole has been active in the recent past.



Cool telescope
Spitzer collects infrared with a beryllium-mirrored telescope that was cooled to -268°C (-450°F) using liquid helium so as not to swamp the weak heat radiation.

Sun shield
Spitzer's ingenious solar shield allows it to continue operating at low temperatures even after its liquid helium coolant has been exhausted.

Mission profile

Spitzer Infrared Space Observatory

Launch date: 25 August 2003
Launch vehicle: Delta II
Mass: 950kg
Telescope diameter: 0.85m
Mission: Spitzer was designed to study a wide range of objects, from star-forming nebulas and newborn solar systems to distant galaxies. Although the coolant required for its primary mission was exhausted in May 2009, it is still operational in its 'Warm Mission' phase.
Key discoveries: Spitzer's infrared vision allowed it to pierce the dust that blocks our view of the galactic centre, providing the first detailed images of the giant star clusters and tortured gas clouds found in the region.

Map of the Milky Way

Zone of Avoidance
This mysterious region lies on the opposite side of the hub from our Solar System, and is largely unknown. As well as features of the Milky Way, it also conceals galaxies in the space beyond.

Carina-Sagittarius Arm
This minor arm runs in front of both the Scutum-Centaurus arm and the galactic hub as seen from Earth. It contains some of the richest starfields and most impressive nebulas in the sky.

5kpc ring
This ring of stars, gas and dust is thought to be the biggest and brightest centre of star formation within our galaxy.

Perseus Arm
This major arm emerges on the far side of the central bar, and wraps its way around the opposite side of the sky from the hub, as seen from Earth. It contains many of the rich starfields and nebulas seen in the northern Milky Way.

Galactic halo
The halo region above and below the galaxy's flattened disc is home to stray ancient stars and globular clusters – huge balls of long-lived red and yellow stars.

You are here
Our Solar System lies roughly 26,000 light years from the galactic centre, about half way between the hub and the galaxy's visible edge. Here, the Sun orbits the centre every 200 million years.

Scutum-Centaurus Arm
This major spiral arm emerges from the near end of the galaxy's central bar, but lies largely on the opposite side of the hub from Earth.

SagDEG
Discovered in 1994 as an unusual concentration of stars on the far side of the galactic hub, the Sagittarius Dwarf Elliptical is a small galaxy in the process of being torn to shreds by the Milky Way's gravity.

Sagittarius A*
The supermassive black hole at the centre of our galaxy weighs more than 4 million Suns, but only gives its presence away through X-ray and radio emission.

Galactic hub
The central bulge of the Milky Way is roughly 8,000 light years in diameter and dominated by tightly packed, long-lived red and yellow stars.

winds blowing out from massive stars. Infrared telescopes, meanwhile, show the distribution of stars themselves - the region is home to two of the largest open clusters in the galaxy, the Quintuplet Cluster and the Arches Cluster. A third cluster surrounds the Sagittarius A* region itself, but while its individual stars have been mapped, none coincides exactly with the mysterious radio source.

Since the Seventies, astronomers have suspected that Sagittarius A* might mark the location of an invisible black hole with the mass of millions of Suns, but the evidence to back this up has only recently been found. By mapping the central star cluster over several years, astronomers have plotted the orbits of two stars that orbit the object every few years. Based on the speed of these stars, Sagittarius A* must contain the mass of at least 4 million Suns concentrated in a region roughly the size of Uranus's orbit around the Sun. With such enormous density, it can only be a supermassive black hole.

However, Sagittarius A* seems surprisingly quiet compared to similar objects elsewhere in the universe - other supermassive black holes in distant galaxies wreak havoc with their surroundings. Astronomers think the big difference is that these black holes are feeding on material that strays too close. Sagittarius A*, on the other hand, seems to have long ago cleared out its immediate surroundings, and anything that still orbits in the central region stays safely out of reach.

Recent discoveries, however, suggest that Sagittarius A* may have been active surprisingly recently. In 2007, NASA's Chandra satellite discovered X-ray 'echoes', created as radiation when an event roughly 50 years previously affected gas clouds near the central black hole. It seems likely that Sagittarius A* took a substantial snack at this time, when a large gas cloud strayed too close. And in 2010, the Fermi Gamma-ray Space Telescope found evidence for an even larger outburst thousands of years ago.

There's one final question that's worth asking about our galaxy - where does it end? Although the spiral arms seem to lose their intensity and the number of disc stars falls off dramatically over 50,000 light years from the hub, a disc of neutral hydrogen gas extends out to almost 100,000 light years and seems to retain the overall spiral structure. The Milky Way's gravitational influence extends even further - the halo of stars and globular clusters reaches out to around 150,000 light years or more. However, beyond this distance the orbits of halo objects are disrupted by two interlopers - the Magellanic Clouds. Until recently, these two irregular clouds of gas were believed to be in orbit around our galaxy, but it now seems that they are merely passing by on their own paths through space.

On a larger scale, the Milky Way is one of the major components of the Local Group - a galaxy cluster 10 million light years across. The other is the Andromeda Galaxy, some 2.5 million light years away. These two galaxies exert a strong influence on everything in their vicinity, and are approaching each other at 110 kilometres per second. They will eventually collide and merge together about 4 billion years from now in a process that will signal the end of the Milky Way as an independent galaxy.

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Kuipers is the only Dutch astronaut to have flown into space twice

The man who caught the Dragon

Grabbing a capsule full of supplies with a robot arm in low-Earth orbit? It's a job that posed no problem for Dutch ISS astronaut André Kuipers

Interviewed by Jonathan O'Callaghan

André Kuipers
Age: 54
First mission: Soyuz TMA-4
No. of missions: 2
Time in space: 206 days

Born on 5 October 1958, André Kuipers is a Dutch physician and ESA astronaut who has flown into space twice. His first mission in April 2004 was a short-duration stay on the ISS of a week and a half. His second mission launched to the ISS on 21 December 2011 and returned on 1 July 2012, during which time he was responsible for berthing SpaceX's Dragon spacecraft, the first private vehicle to dock with the ISS.

Why did you decide to become an astronaut?
It all started when I was about 12 with some science-fiction books I had from my grandmother. That triggered my fantasy, but it was still a boy's dream. I grew up in the period that we landed on the Moon and launched Skylab, and then the Space Shuttle was built, so I saw all these beautiful pictures. And then the European Space Agency (ESA) was founded [in 1975], and they had a Dutch astronaut, and I thought 'hey, wait a minute, maybe it's not just a boy's dream adventure'. I saw a picture of John Young in the Space Shuttle with glasses, and I had been wearing glasses since I was 12, so I began to realise that these were normal people and not just test pilots.

What sort of training did you have to do for your first mission?
Well, because the ESA needed to select astronauts from smaller countries like Holland, there was initially no direct flight for us. So I began training all by myself, and I did some basic training in Star City [in Russia]. I was studying orbital mechanics, planetary science and some other basic stuff until Holland decided to sponsor my flight, and then I started training for the DELTA mission [on Soyuz TMA-4 in April 2004].

How did it feel to be selected for the DELTA mission?
I'd been looking forward to it for many years. You hope that nothing goes wrong because the biggest worry for astronauts is not the launch but that somebody cancels the flight or you get disqualified, so that's always a threat. So I was very pleased when I was walking to the rocket, I thought 'this is it, it's going to happen,' and it was very exciting. You feel it in your stomach as if you're sitting in a rollercoaster, you're in your seatbelt and there's no way back!

What was that first launch on the Soyuz like?
You sort of know what's coming from training. You have been in a centrifuge, you did the launch sequence so many times and all the things that could go wrong, and you know the sound of the commands, so everything comes together. The actual launch was much more relaxed than the simulation because in the simulator they design it so that everything goes wrong. There's always something failing or you lose thrust or you don't disconnect from the third stage, problems to solve like that. In reality everything is clean and quiet, so you concentrate on the screen and see if anything is wrong but everything is okay, so it's even more relaxing.

What was your role on that mission?
Well, I'm a medical doctor, and when I wanted to become an astronaut I knew that medical doctors had been to space. So I expected that I would become a mission specialist, probably on the Space Shuttle. But then they told me I was going to Russia to fly on the two-person Soyuz, and I would be flying the left seat [the pilot's seat]. That was very surprising because normally the foreign astronauts would fly on the right seat where you don't do much, and you have a lot less tasks. And normally the ones who flew in the left seat were test pilots. So I would be the first non-pilot and non-engineer to fly for my first flight in the left seat.

Was it hard to pilot the Soyuz?
It was quite a challenge but very interesting. The hardest part was that [everything in the Soyuz is] in Russian and abbreviated, so having to learn abbreviated technical Russian was quite a challenge!

How long was that mission?
It was a short-duration mission, so it was 11 days of which nine were in the International Space Station. I

> "The actual launch was much more relaxed than the simulation because in the simulator… everything goes wrong"

The Dragon spacecraft was caught by Kuipers and berthed with the ISS for the first time on 25 May 2012

Kuipers looks through the window of the Destiny module during his first stay on the ISS

brought one crewmember up, because this was in the time that we could have only two people on board the Soyuz because of the Space Shuttle Columbia disaster, and we couldn't get enough resources and consumables to the station for a larger crew, so there were only two permanent crewmembers on the station. Then I flew back with another crewmember on the previous Soyuz spacecraft that was already docked with the station. It was great and so interesting, I thought 'wow, I don't want to go back, I want to be here for a longer time.' Then I already knew that I would try to fly again.

So, when you were eventually selected for the long-duration Expedition 30/31 mission, was your training the same?
No, this was totally different. It was a new Soyuz spacecraft, so I had to do a lot of new training with new software and other flight control systems. Also, on the DELTA mission, I only had to do some experiments on the International Space Station. I knew how to make food and use the toilet in the Russian segments, and in the American lab I knew how to do my experiments. But now we had a totally different situation because I was assigned to fly as a flight engineer for the ISS, and the ISS was now twice as big, so I had to know all the systems on board. The Japanese module was there, the Columbus module, the Cupola module, all these things were new. So I had to learn how to be an operator and a specialist in these areas. I became a specialist for Columbus, the Japanese module, the robotic arm, spacewalks and the ATV [ESA's Automated Transfer Vehicle], and I became an operator on the US segment. And I was also a specialist for the Dragon capsule capture and berthing.

So, ultimately, you were tasked with bringing the first Dragon to the ISS?
Yes, together with [NASA astronaut] Don Pettit. Several crews were trained for the event but things were postponed so finally it came down to us. Because this was the first Dragon we didn't know if it would behave properly, so my task was to send it back and forwards together with the ground. I also gave commands for Dragon to switch its lights on and off, to see if the signals were going through properly and that it was flying to our wishes.

Did anything go wrong?
There was one moment where we saw Dragon retreating and I thought 'oh, we didn't give that command, what's going on?' But it turned out the ground [control] did that because it was having problems with its rangefinder. For a moment we thought it wasn't going to work, but then they said it was okay to approach again.

How did the capture go?
For the capture I was controlling the Dragon and checking all the distances, making sure that it was in a free drift. You don't want either the station or the Dragon to move around when you're trying to grab it with the arm so it has to go in free drift so it doesn't move. Then I gave Don the go-ahead and he grappled it, and then I took over and turned the Dragon around. It was interesting with this arm because you have three ways to move with the angles of the joints, and I got to use all three of them which was nice because you train for that for many years, so it's nice to get to use all the possibilities of this arm. And then we berthed it with the ISS, which isn't the same as a docking like the ATV or Soyuz. A berthing is where you pull it in yourself. This was a great moment, an operational highlight, and maybe even the highlight of my career, because this is why you train all this time. I mean you really have this spaceship in your hands, and it's the very first one, and then you click it and connect it with the station. It was a great moment.

What was the feeling on the station at the time?
We felt excited because everybody in the space world was watching us because this was the start of the commercialisation of human space flight. We had that already with rockets and satellites, but for human spaceflight we hadn't seen [commercialisation] yet, and this was the first one. And so I realised it was the start of a new era, with government agencies hiring SpaceX or Orbital Sciences or whatever to bring goods and even future astronauts to the space station. Then the agencies can continue with exploration, and this is the way it should be. So this is how I expect things will develop, that NASA and ESA and others will altogether go back to the Moon, then asteroids and Mars, and leave low-Earth orbit to more commercial activities like industry and tourism.

Would you like to go to space again?
I would love to fly again. It's not very likely that I will fly again for the European Space Agency, but you never know what kind of developments are coming. With SpaceX, for example, if the US is flying its astronauts with the Dragon in the future then there are more spaces left in the Soyuz that might be filled with tourists like we saw in the past. Another option is maybe the Chinese. What's going to happen there? Is there going to be co-operation or not? I expect that things will come closer and that you might see other astronauts flying with the Chinese as well. So you never know, these things can develop in strange ways.

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Secrets of the Oort cloud

At the fringes of the Solar System lies a vast cloud of icy bodies. Like a museum, this region holds the pieces of the Solar System as it first formed

This icy swarm was first proposed by Dutch astronomer Jan Hendrik Oort, who said that some comets might come from a cloud of millions of small objects at the edge of the Solar System.

Some comets are frequent visitors to our Solar System, such as Halley's Comet. These are believed to come from an area just beyond Neptune, known as the Kuiper belt. The Oort cloud comets, however, are from a different realm altogether. The cloud probably has anywhere from 0.1 to 2 trillion icy comets lurking between 5,000 and 100,000 AU from the Sun.

We haven't been able to spot objects in the cloud yet, because it is so far from Earth and the objects would be tiny. This leaves them out of reach of many of today's telescopes. But using numerical models, astronomers have come up with a typical life cycle of a comet originating from this cloud.

Every so often, a stray bit of gravity kicks an icy body out of the cloud and towards the inner Solar System. They then get sucked in to the Sun's gravitational well and fly past Earth.

As a comet gets closer to the Sun, heat and solar particles hit it and begin to melt the frozen ice. Gas and debris stretches behind the comet, producing spectacular tails that are sometimes visible from our planet.

Since these comets come from so far away, it can take thousands of years for them to make one trip around the Sun. Jan Oort observed that these so-called 'long-period comets' had a similar inclination, which implied that they must come from a similar origin.

The Oort cloud is so vast that it has at least two separate regions: an outer cloud and a more populated Hills cloud in the inner region. The inner region, first detailed by astronomer JG Hills, would occur as the gravity of passing stars and Jupiter pulled on the icy bodies after their formation.

Since the Oort cloud is too far away for us to study right now, our best bet in understanding its composition is to observe the comets that swing by our Solar System. It's hard to send a spacecraft out to comets because they are so unpredictable. Funding a mission takes years, and then there's the work that needs to go into plotting trajectories to make sure the spacecraft is in the right place at the right time.

For that reason, the spacecraft that have visited comets, such as NASA's Stardust, stick to those that have predictable, regular trips through the Solar System. For the Oort comets, astronomers rely on observations from the ground or space telescopes.

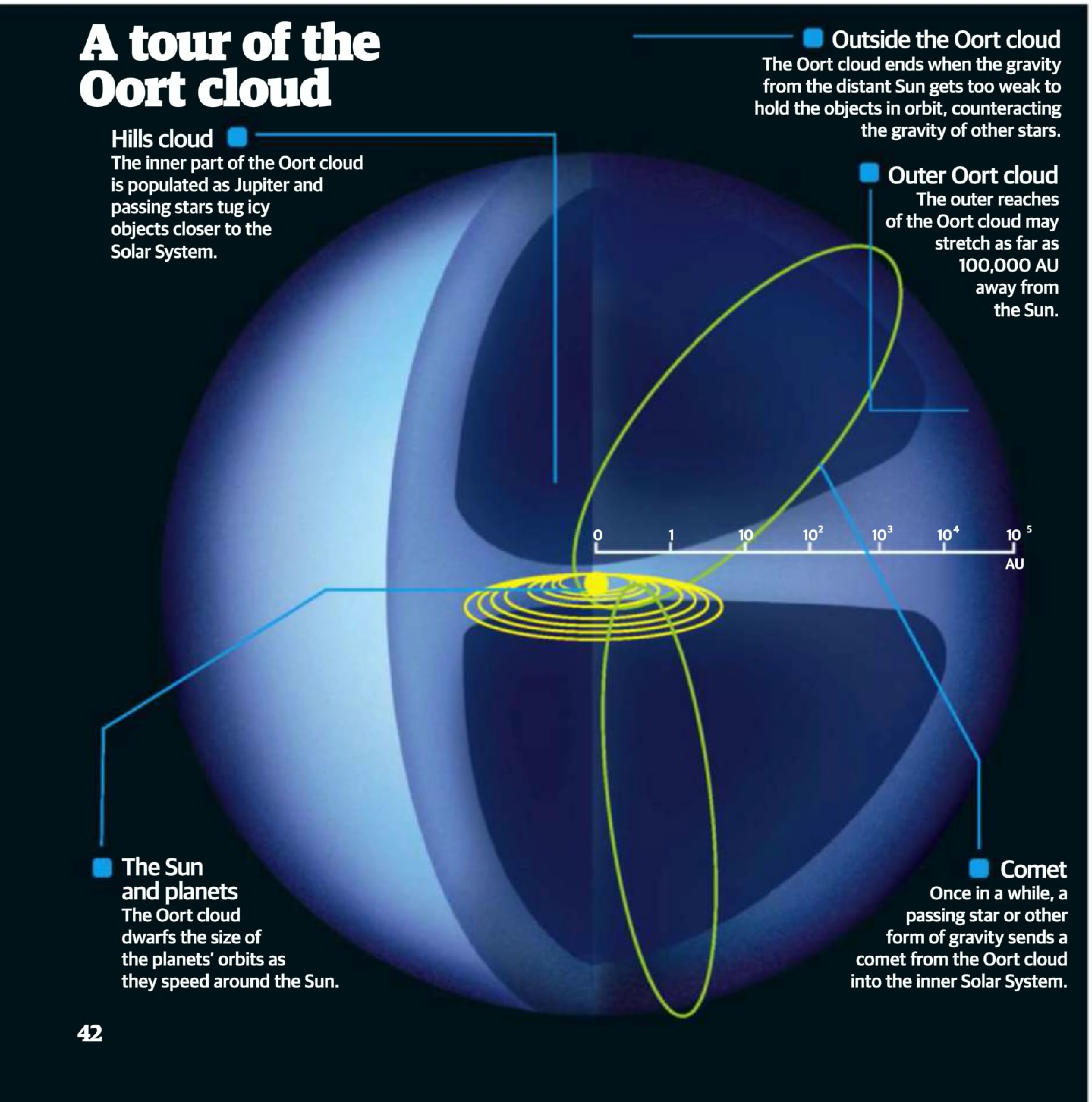
We can still see quite a bit from a distance. In 1997, scientists used two NASA observatories - the Hubble Space Telescope and the International Ultraviolet Explorer - to check out what was happening as Comet Hale-Bopp swung near the Earth.

Astronomers were surprised to see that water ice in the nucleus of the comet changed directly from a frozen state to a gas (called sublimation) at a different rate than other types of ices on the comet. This essentially rewrote our understanding of comet nuclei.

Before, we thought that the comet's water ice acted as a container for all the other ices. If that had been the case, we would have seen the sublimation happen at similar rates.

Astronomers are now awaiting another Oort cloud visitor: Comet ISON. It is on its way to the inner Solar System and, if predictions are right, will put on a bright show around November and December 2013. ■

A tour of the Oort cloud



Outside the Oort cloud
The Oort cloud ends when the gravity from the distant Sun gets too weak to hold the objects in orbit, counteracting the gravity of other stars.

Hills cloud
The inner part of the Oort cloud is populated as Jupiter and passing stars tug icy objects closer to the Solar System.

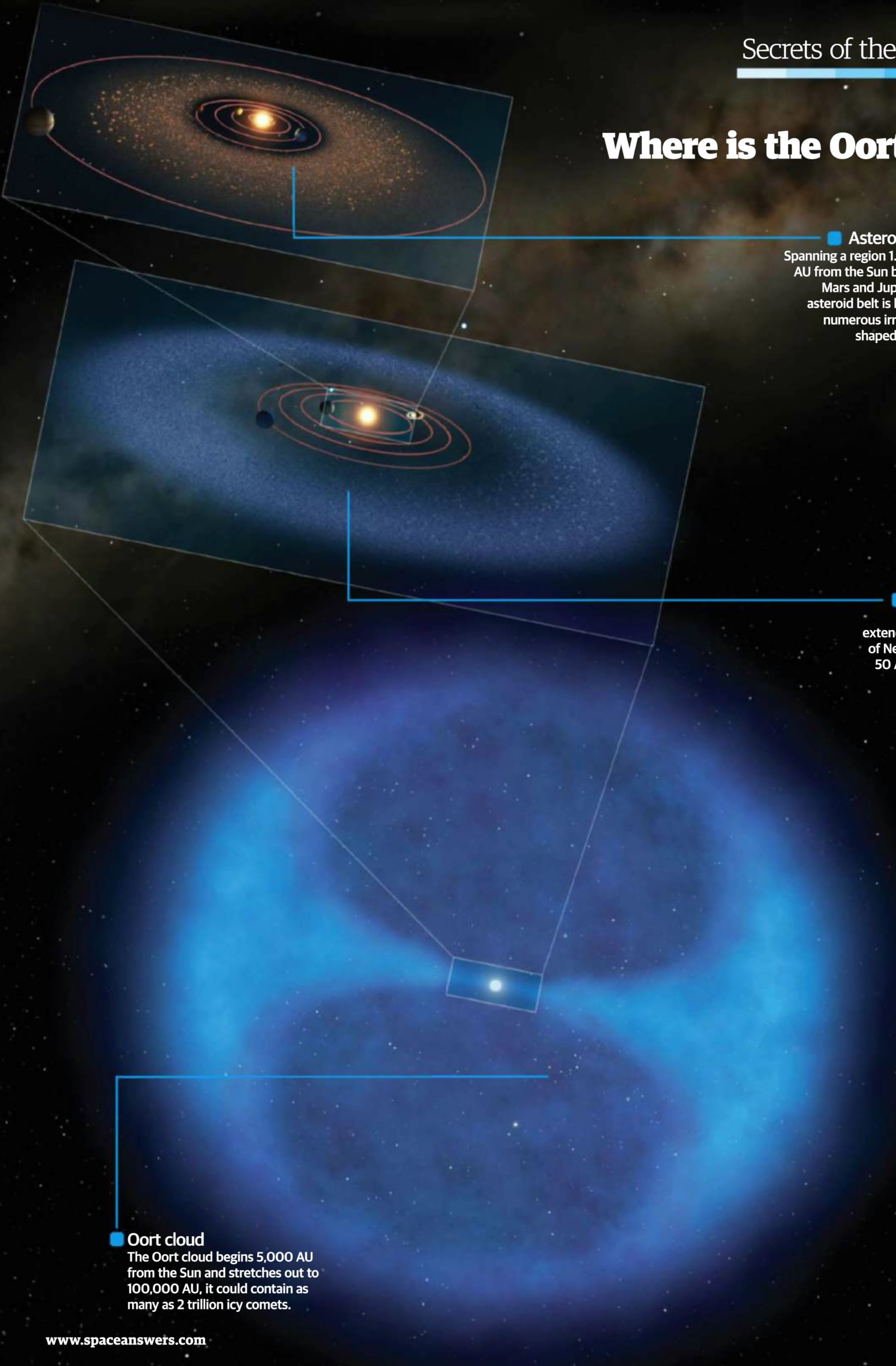
Outer Oort cloud
The outer reaches of the Oort cloud may stretch as far as 100,000 AU away from the Sun.

The Sun and planets
The Oort cloud dwarfs the size of the planets' orbits as they speed around the Sun.

Comet
Once in a while, a passing star or other form of gravity sends a comet from the Oort cloud into the inner Solar System.

The existence of the Oort cloud was theorised by astronomer Jan Oort

Where is the Oort cloud?



Asteroid belt
Spanning a region 1.8 to 4.5 AU from the Sun between Mars and Jupiter, the asteroid belt is home to numerous irregularly shaped bodies.

Kuiper belt
The Kuiper belt extends from the orbit of Neptune to around 50 AU from the Sun.

Oort cloud
The Oort cloud begins 5,000 AU from the Sun and stretches out to 100,000 AU, it could contain as many as 2 trillion icy comets.

© NASA; Alamy; SPL

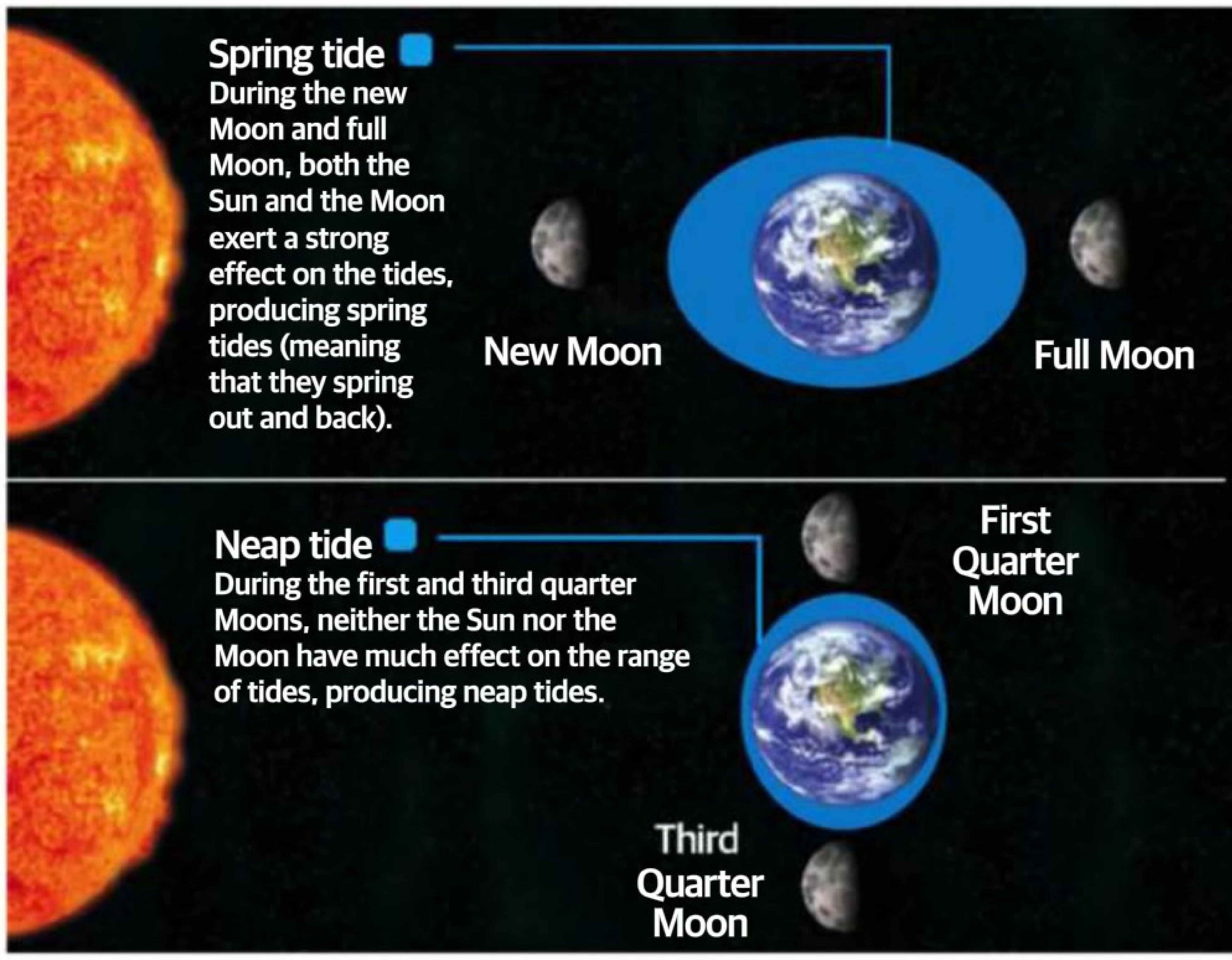
All About... THE MOON

Written by Shanna Freeman

The Moon is the Earth's only natural satellite, and the only celestial body that we've set foot on other than our own planet. But even though we know more about it than any other celestial body, the Moon continues to fascinate

The Moon and tides

Along with the Sun, the Moon exerts serious force on the Earth's tides. Whether the tides vary widely or not much at all has a lot to do with the interactions between the solar and lunar cycles. When they are together, their combined effects produce tidal variations called spring tides – high tides are very high and low tides are very low. If the Sun and Moon are on the opposite sides of the sky, they nullify each others' effects, producing neap tides – with little variation.



Spring tide
During the new Moon and full Moon, both the Sun and the Moon exert a strong effect on the tides, producing spring tides (meaning that they spring out and back).

Neap tide
During the first and third quarter Moons, neither the Sun nor the Moon have much effect on the range of tides, producing neap tides.

Because we can easily discern features on the Moon with the naked eye, it has been a sense of wonder to us since ancient times. The Moon is the brightest object in our sky after the Sun, and influences everything from our oceans to our calendars. It's always been 'the Moon' because we didn't know that there were any others. Once Galileo discovered in 1610 that Jupiter had satellites, we've used the word 'moon' to describe celestial bodies that orbit larger bodies, which orbit stars. Since the Moon has always been so present, it might not seem worth studying. Yet there's a reason why we continue to return to it – we still have plenty to learn from our satellite.

The Moon is the fifth-largest and second-densest satellite in the Solar System. Its diameter is 27 per cent of Earth's at 3,476 kilometres (2,160 miles), while its mean density is 60 per cent that of the Earth's. This makes the Moon the largest satellite in size relative to the planet that it orbits. The Moon is also unusual because its orbit is more closely aligned to the plane of the ecliptic – the plane in which the Earth orbits. Most planetary satellites orbit closer to their planet's equatorial plane, but the Moon is inclined from the plane of the ecliptic by approximately 5.1 degrees.

Its average distance from the Earth is 384,400 kilometres (239,000 miles), and it completes an orbit once every 27.3 days. The Moon is in synchronous rotation with the Earth – its rotation and orbital period are the same – so the same side is almost always facing our planet. This is called the 'near side' of the Moon, while the opposite side is the 'far' or 'dark' side (although it gets illuminated just as often as the near side). This hasn't always been the case; the Moon used to rotate faster, but the influence of the Earth caused it to slow and become locked.

Although we say that we can only see one side of the Moon at a time, that's not strictly true. The Moon's orbit isn't quite circular – it has an eccentricity of 0.0549. The Moon also wobbles a bit along its orbit. These two factors cause some variations in how much of the Moon that we see, called librations. When the Moon is closest to the Earth, called the perigee, it orbits slightly slower than it rotates. This means that we can actually get a glimpse of about eight degrees of longitude of its eastern far side. When the Moon is at its furthest point away in its orbit, the apogee, its orbit is slightly faster than its rotation. So we get a glimpse of eight degrees of longitude on its western far side. This is called longitudinal libration.

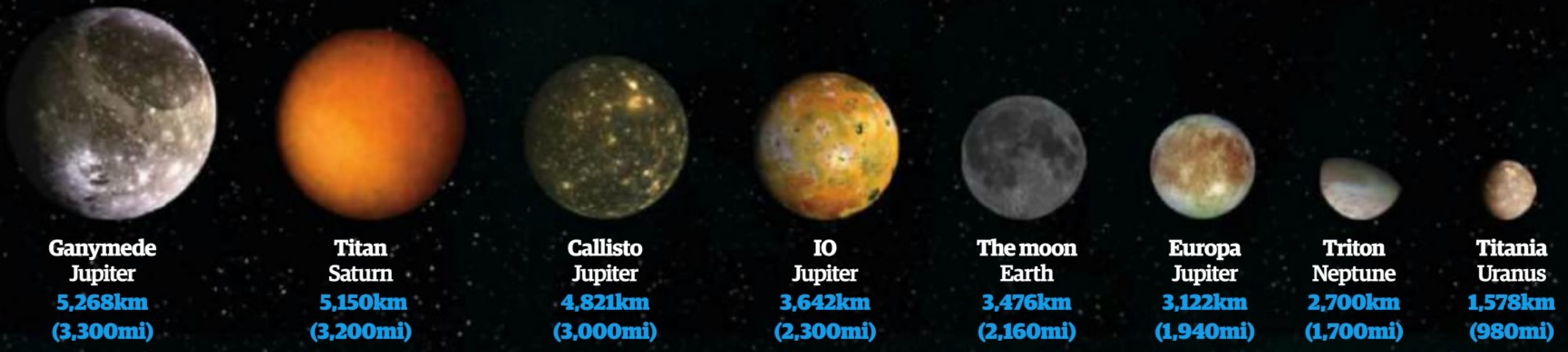
The Moon also appears to rotate towards and away from the Earth. This is due to the 5.1-degree inclination of its orbit, as well as the 1.5-degree tilt of the Moon's equator to the plane of the ecliptic. This results in us seeing about 6.5 degrees of latitude on the far side along both the sides of the poles. The Moon's orbit also means that it appears to move about 13 degrees across the sky each day, and this movement accounts for the lunar phases.

The Moon's gravitational pull has a strong effect on the Earth. The most obvious effect to us is the tides. High tide occurs when the level of water at the coastline rises, and low tide occurs when the water rushes further out. While some coastlines experience one high tide and one low tide per day, of equal strength, others have different strengths, timing and numbers of tides. Measuring and predicting these tides is incredibly important for everything from fishing to navigating intercoastal waterways. We use the term 'tides' to describe oceanic tides, but tides also occur on a smaller level in lakes as well as the Earth's atmosphere and crust.

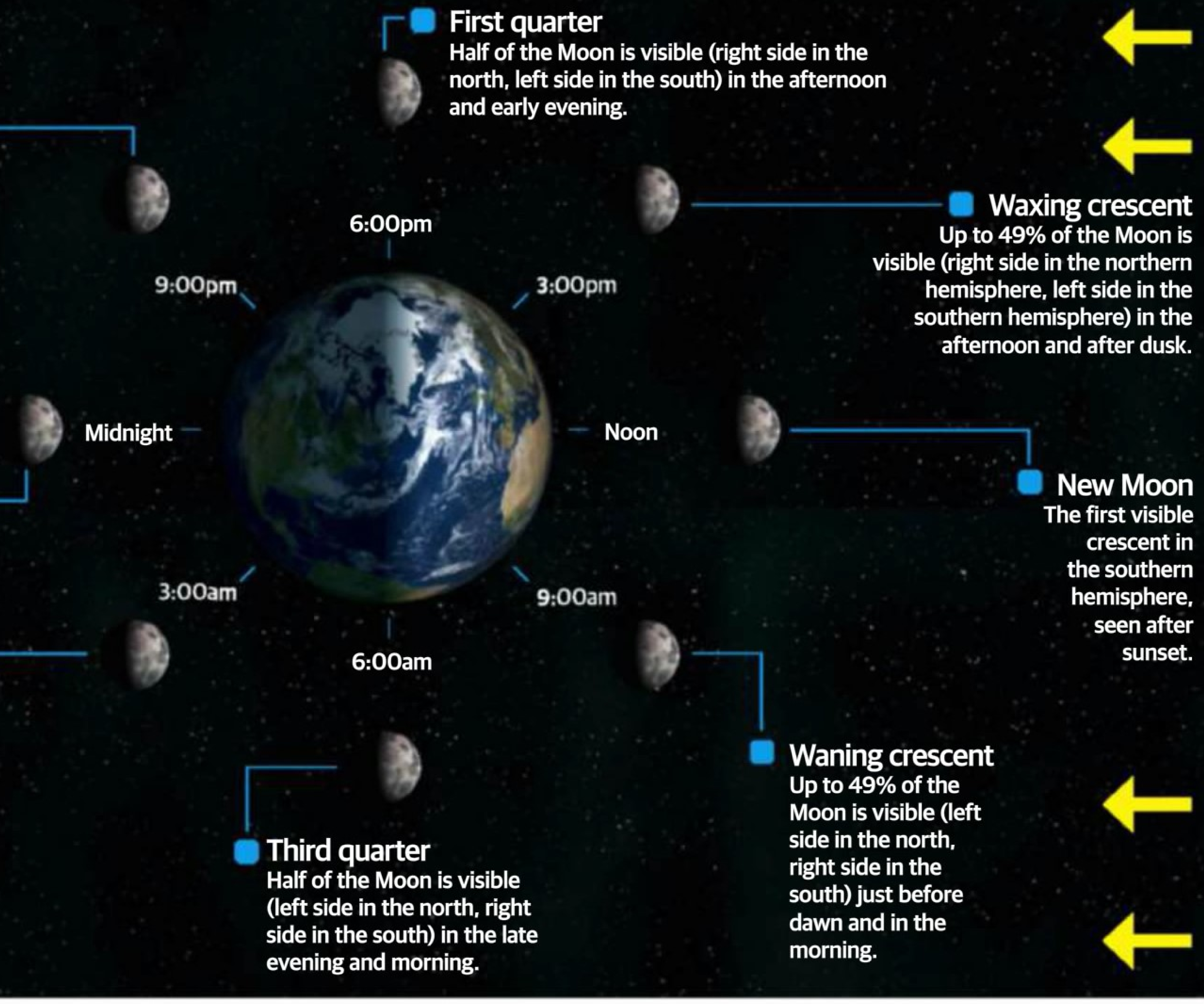
Scientists believe that the Moon formed when a huge celestial body about the size of Mars (which has been given the name Theia) impacted with a young Earth. This is known as the giant impact hypothesis. This force sent debris out into Earth's orbit, which fused to form the Moon. However, in 2012, an analysis of rock samples taken from the Moon during the Apollo missions showed that the Moon's composition is almost identical to Earth's. This calls the giant impact hypothesis into question, because previously we thought that at least some of the Moon's material had to have come from Theia.

> "The Moon is the fifth-largest and second-densest satellite in the Solar System. Its diameter is 27% of Earth's"

How the Moon measures up



The Moon's orbit



First quarter
Half of the Moon is visible (right side in the north, left side in the south) in the afternoon and early evening.

Waxing gibbous
Between 51 and 99% of the Moon is visible (right side in the north, left side in the south) in the later afternoon and most of the evening.

Waxing crescent
Up to 49% of the Moon is visible (right side in the northern hemisphere, left side in the southern hemisphere) in the afternoon and after dusk.

Full Moon
The entire Moon is visible all night long.

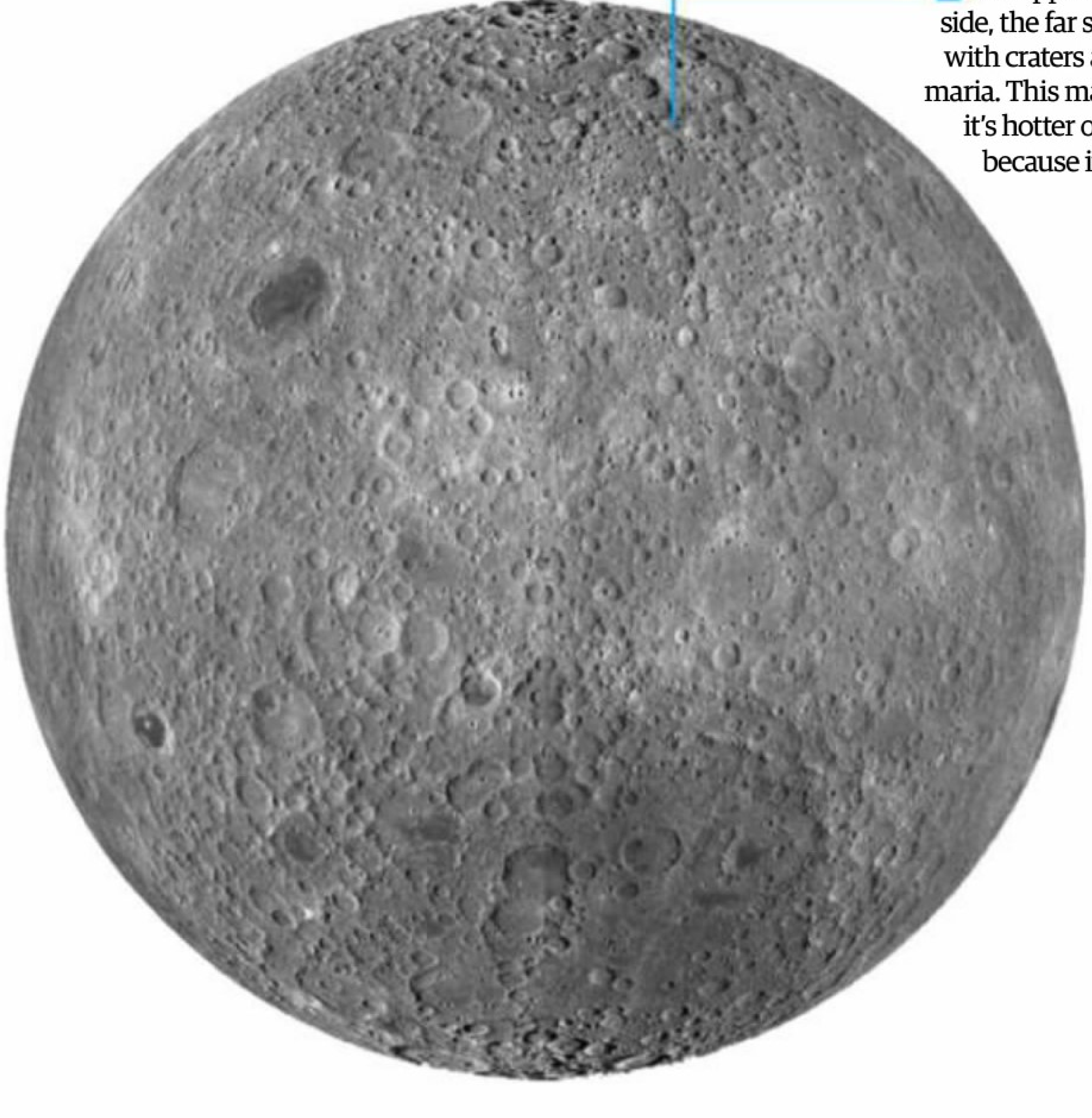
New Moon
The first visible crescent in the southern hemisphere, seen after sunset.

Waning gibbous
Between 51 and 99% of the Moon is visible (left side in the north, right side in the south) for most of the evening and in the early morning.

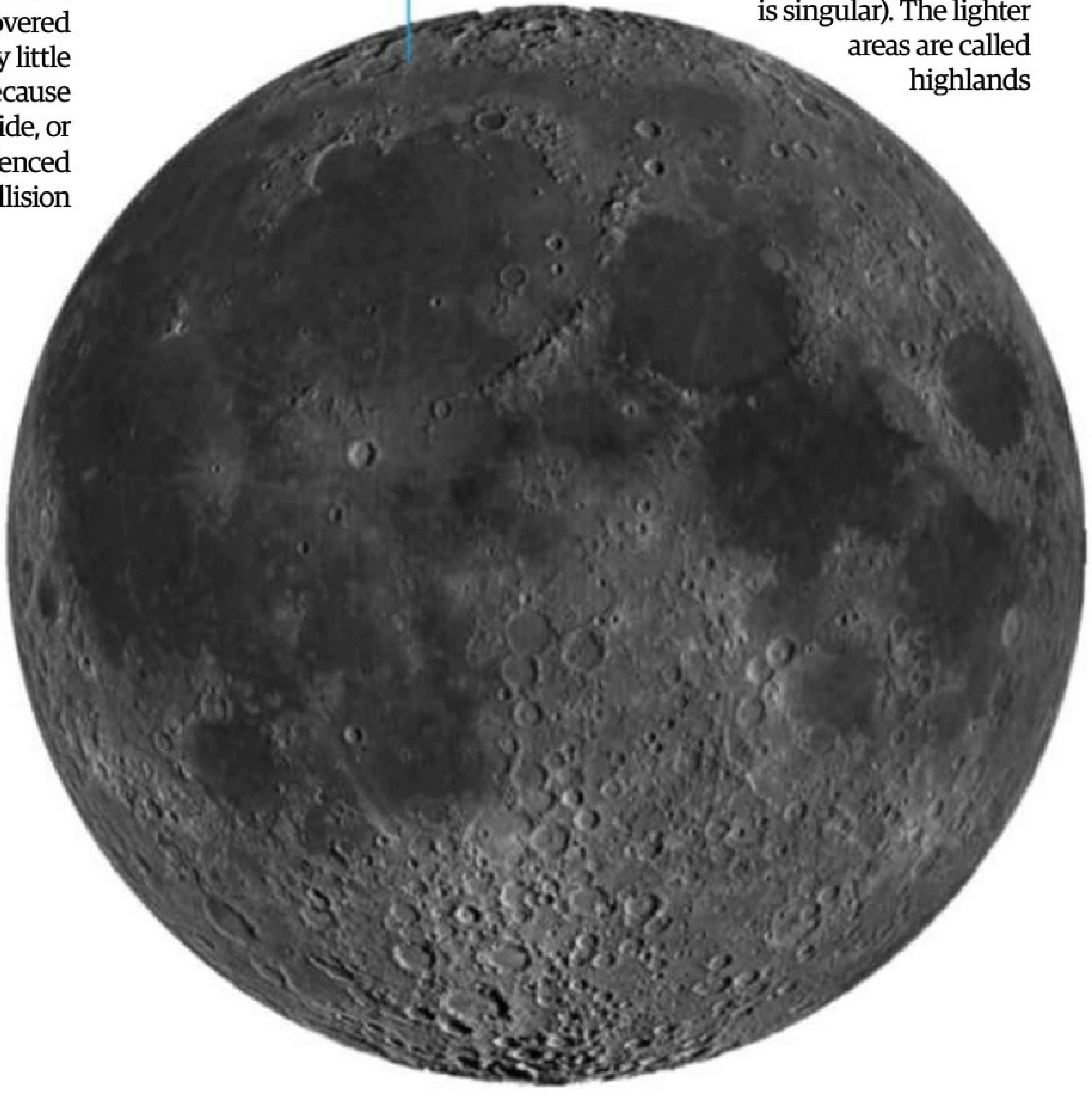
Third quarter
Half of the Moon is visible (left side in the north, right side in the south) in the late evening and morning.

Waning crescent
Up to 49% of the Moon is visible (left side in the north, right side in the south) just before dawn and in the morning.

Two sides of the Moon



As opposed to the near side, the far side is covered with craters and very little maria. This may be because it's hotter on that side, or because it experienced a collision



The near side of the Moon is mostly covered in dark areas that were originally thought to be seas, called maria (mare is singular). The lighter areas are called highlands

The Moon inside and out

The Earth's only known satellite shares some remarkable similarities with our home planet

Although the Moon may seem like a solid rock, it's actually differentiated like the Earth; it has a core, a mantle and a crust. The Moon's structure likely came from the fractional crystallisation of a magma ocean that once covered the Moon. This probably happened not long after the Moon was formed, about 4.5 billion years ago. This means that as the magma ocean cooled, its composition changed as the different minerals within the melt crystallised into solids. The denser materials sank, forming the mantle, while less dense materials floated on top and formed the crust.

We believe that the core is probably very small, with a radius about 20 per cent the total size of the Moon. By contrast, most differentiated celestial bodies have cores about 50 per cent of their total size. The core itself comprises a solid innermost core that is rich in iron as well as nickel and sulphur, with a radius of 240 kilometres (150 miles). This is surrounded by a fluid outer core, with about a 300-kilometre (186-mile) radius. Between the core and the mantle, there's a boundary layer of partially melted iron that has about a 500-kilometre (300-mile) radius. It is also known as the lower mantle. The upper mantle is mafic – rich in magnesium and iron, topped by a crust of igneous rock called anorthosite. It mainly includes the elements aluminium, calcium iron, magnesium and oxygen, with traces of other minerals. We estimate the crust to be around 50 kilometres (31 miles) thick.

The Moon has no plate tectonics, but it does have seismic activity. When astronauts with the Apollo programme visited the Moon, they discovered that there are moonquakes – the Moon's equivalent of earthquakes. Moonquakes aren't nearly as strong as earthquakes, but they can last longer because there's no water to lessen the effects of the vibrations. Seismometers placed by Apollo astronauts showed that the strongest moonquakes are about 5.5 on the Richter scale. There are four different types of moonquakes: shallow, deep, thermal and meteorite. Shallow ones occur just 20 kilometres (12 miles) below the surface, while deep moonquakes can be as deep as 700 kilometres (435 miles). These deep moonquakes are probably related to stresses on the Moon caused by its eccentric orbit and gravitational interactions between it and the Earth. Thermal earthquakes occur when the crust of the Moon heats and expands. This happens when the Moon is bathed in sunlight again after its two-week-long night. Finally, meteorites hitting the Moon can also cause a type of moonquake. However, shallow moonquakes are the strongest and most common. Nearly 30 of them were recorded between 1972 and 1977 by seismometers (turned off in 1977) that were left on the Moon's surface. This seismic data has helped us to determine the Moon's internal composition.

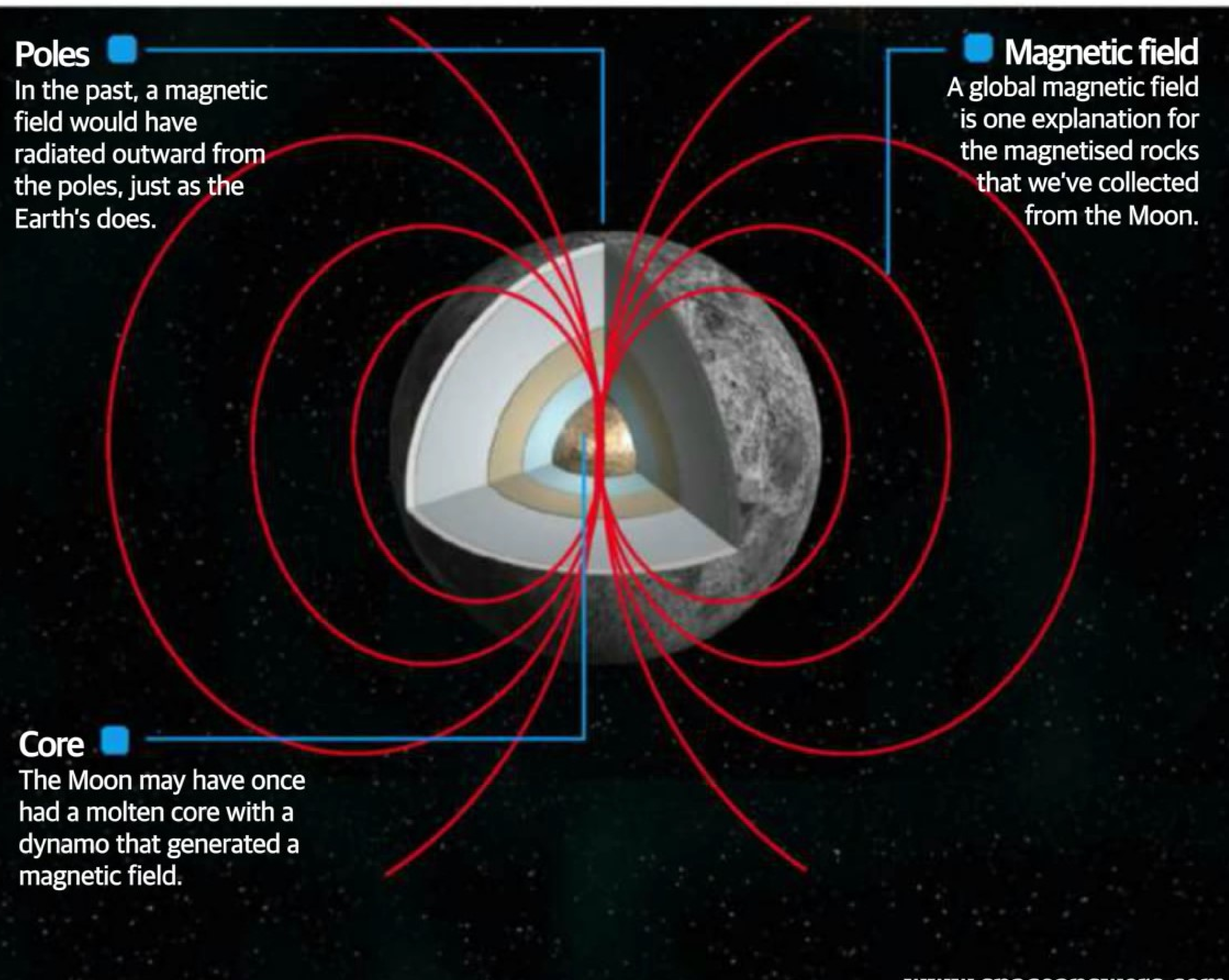
The dominating feature on the near side of the Moon's surface, called maria, are the result of ancient volcanic activity. These vast, dark plains are basalts – igneous rock that formed after lava erupted due to partial melting within the mantle. These basalts show that the Moon's mantle is much higher in iron than the Earth's, and has a varied composition. Some basalts are very high in titanium, while others are higher in minerals like olivine. For the most part, they flowed into impact basins.

These basalt maria have influenced the Moon's gravitational field because they're so rich in iron. The gravitational field contains mascons, big positive gravitational anomalies that influence how spacecraft orbit the Moon. They're also a bit of a mystery, however; the maria can't explain all of the mascons that have been tracked by the Doppler effect on the radio signals emitted by spacecraft that orbit the Moon. And there are also some large maria without associated mascons. ■

> "The Apollo astronauts discovered seismic activity on the Moon"

The magnetic field mystery

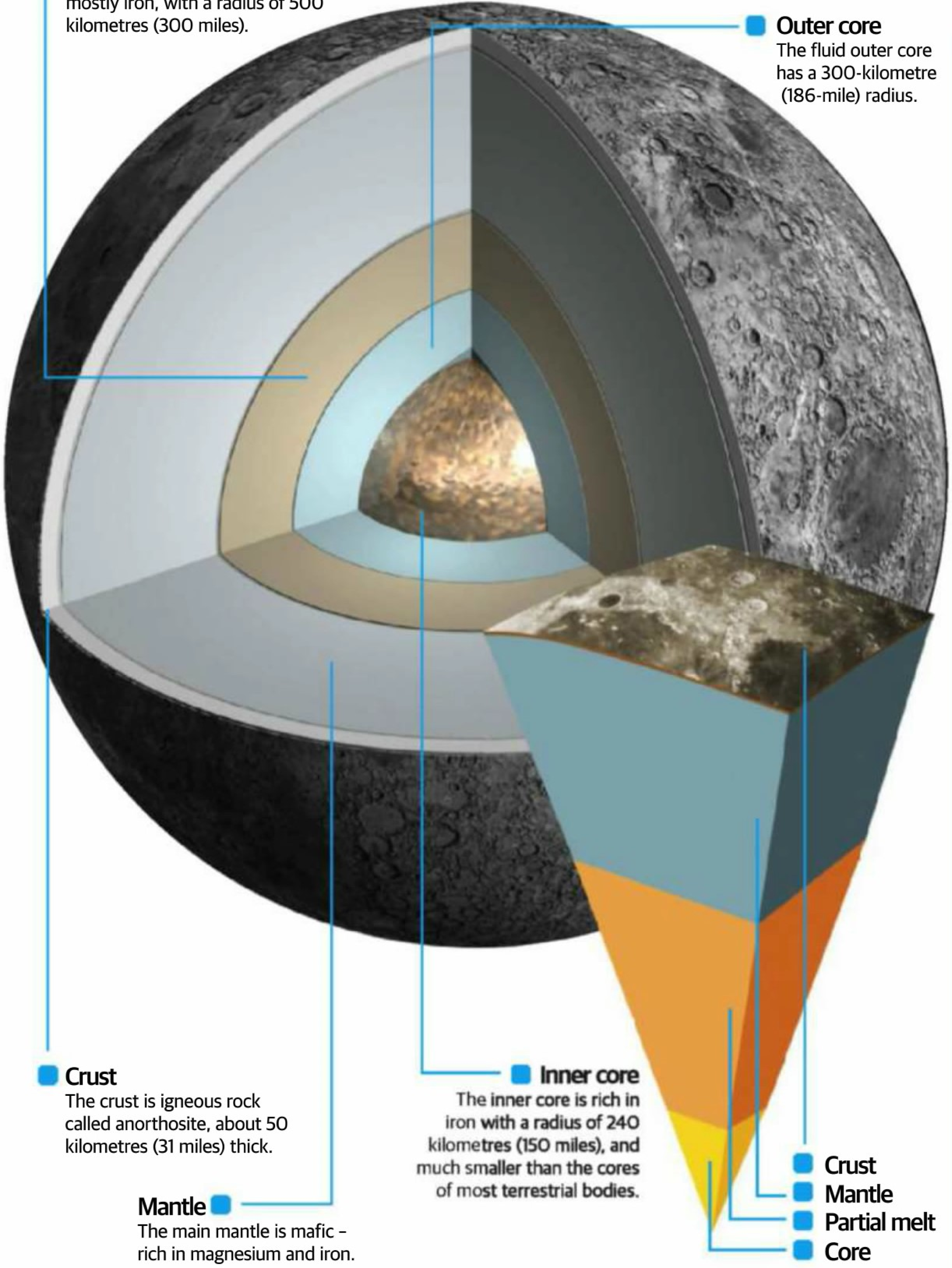
The Moon does have an external magnetic field – it's weak, less than one-hundredth that of the Earth's magnetic field. It's not a dipolar magnetic field like the Earth, which has a field that radiates outward from the north and south poles. So where did this magnetism come from? Researchers believe that the Moon once did have a dipole magnetic field, created by a dynamo – a convecting liquid core of molten metal. But we aren't sure what powered that dynamo. It could have worked like the Earth's dynamo. The Earth's dynamo powers itself, as elemental radioactive decay maintains convection in the core of our planet. The Moon could also have had a dynamo powered by the cooling of elements at the core. Yet if this were true, the magnetic field would have been completely gone about 4 billion years ago because the core is so small. Yet we have discovered magnetised lunar rocks that are younger than this. Another theory is that the Moon's dynamo was powered by the pull of the Earth's gravity when they were much closer together, or that impacts from large asteroids generated the magnetic field.



Poles
In the past, a magnetic field would have radiated outward from the poles, just as the Earth's does.

Magnetic field
A global magnetic field is one explanation for the magnetised rocks that we've collected from the Moon.

Core
The Moon may have once had a molten core with a dynamo that generated a magnetic field.



Partial melt
This partially melted layer is mostly iron, with a radius of 500 kilometres (300 miles).

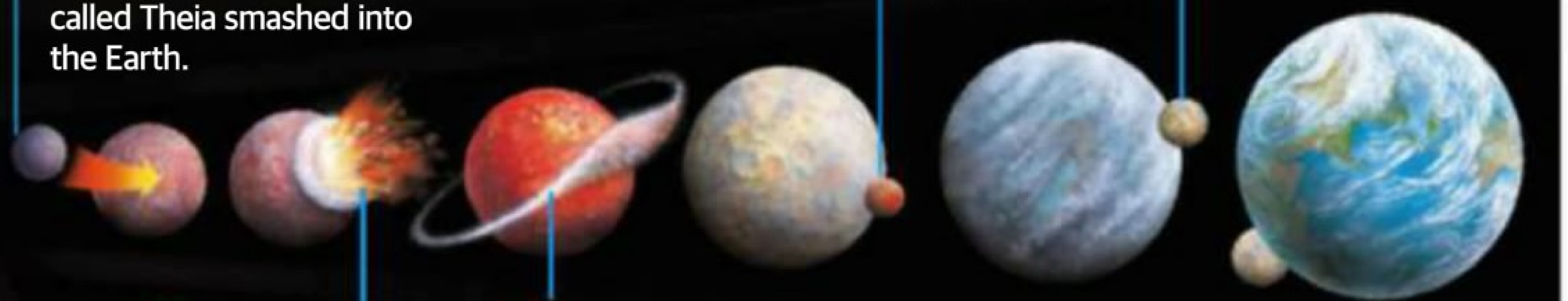
Outer core
The fluid outer core has a 300-kilometre (186-mile) radius.

Crust
The crust is igneous rock called anorthosite, about 50 kilometres (31 miles) thick.

Inner core
The inner core is rich in iron with a radius of 240 kilometres (150 miles), and much smaller than the cores of most terrestrial bodies.

Mantle
The main mantle is mafic – rich in magnesium and iron.

How the Moon formed



Impact
The giant impact theory posits that another body called Theia smashed into the Earth.

Ejection
Material from both Theia and the Earth was ejected into orbit around the planet.

Material orbit
The ejected material began to orbit in a mass.

Disc formation
As it travelled around the Earth, the material coalesced into a disc.

Moon
Eventually the disc formed into the spheroid that we know as the Moon.

The Moon in numbers

Fascinating facts and figures about Earth's only satellite

400

How many times bigger the Sun is than the Moon. But it's also about 400 times further away from the Earth, which is why they look the same size in the sky

29.5 days

The length of a lunar month. It's longer than the amount of time it takes the Moon to orbit the Earth because the Earth is moving, too

12

The number of people who have actually set foot on the Moon

3.8cm (1.5in)

The distance the Moon is moving away from the Earth each year

13 hours

The amount of time it takes to reach the Moon by rocket

16.6kg (36.5lb)

The amount you would weigh on the Moon if you weighed 100kg (220lb) on the Earth

On the surface

The surface of the Moon is about contrasts: light and dark, hot and cold

The landscape of the Moon is dominated by three main features: maria, terrae and craters. The basalt maria appear dark due to their high iron content and are much more prevalent on the near side of the Moon. Other volcanic features located on the surface of the Moon include domes and rilles. Domes are shield volcanoes that are round and wide with gentle slopes, while rilles are twisting sinuous formations caused by channels of flowing lava.

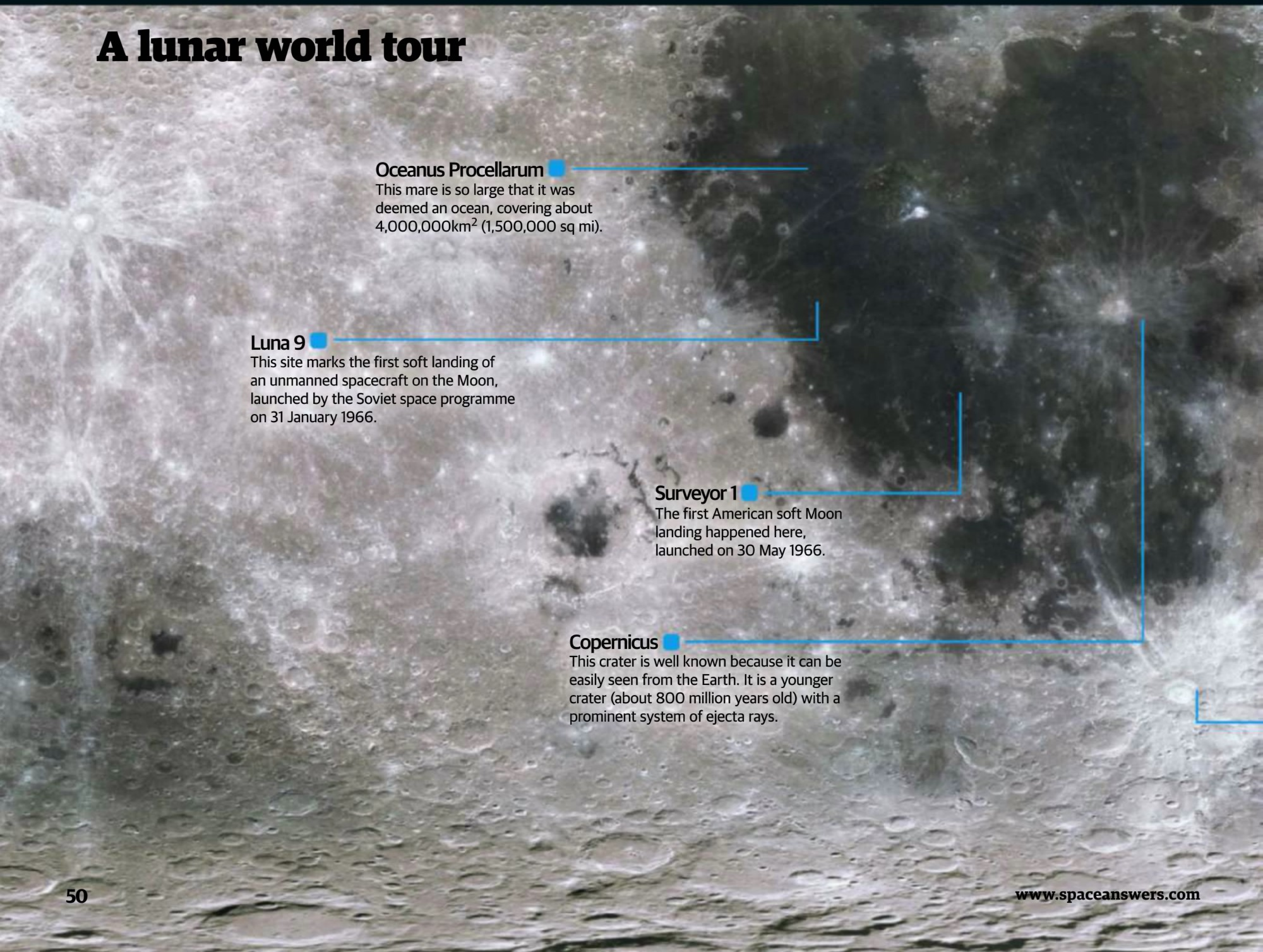
The lighter areas on the Moon are called terrae (terra is singular), or lunar highlands. They are made up of anorthosite, the type of igneous rock that dominates the overall crust of the Moon. While this type of rock can be located in some places on Earth, it's not generally found on the surface due to plate tectonics and deposits. These highlands reflect light from the Sun and make it appear that the Moon is glowing at night.

Both the maria and terrae have impact craters which were formed when asteroids and comets struck the surface of the Moon. These craters range in size from very tiny to massive. It is estimated that there are around 300,000 craters on the near side of the Moon that are wider than one kilometre (0.62 miles). The largest impact crater, called the South Pole-Aitken Basin, is about 2,500 kilometres (1,550 miles) in diameter and 13 kilometres (eight miles) deep. The biggest craters also tend to be the oldest, and many are covered in smaller craters. Younger craters have more sharply defined edges, while older ones are often softer and rounder. If the impact was especially large, material may be ejected from the surface to form secondary craters.

In some cases, the basalt eruptions flowed into or over large impact craters called basins. In general, the terrae have far more craters, because the maria are younger in age than the terrae. While the Moon isn't much younger than the Earth, the Earth has processes that continue to change its surface over time, like erosion and plate tectonics. The Moon doesn't experience these, which is why some impact craters are up to 500 million years older than the basalt filling them.

The loose soil on the Moon is called regolith. It's powdery and filled with small rocks. Over time,

A lunar world tour



Oceanus Procellarum
This mare is so large that it was deemed an ocean, covering about 4,000,000km^2 (1,500,000 sq mi).

Luna 9
This site marks the first soft landing of an unmanned spacecraft on the Moon, launched by the Soviet space programme on 31 January 1966.

Surveyor 1
The first American soft Moon landing happened here, launched on 30 May 1966.

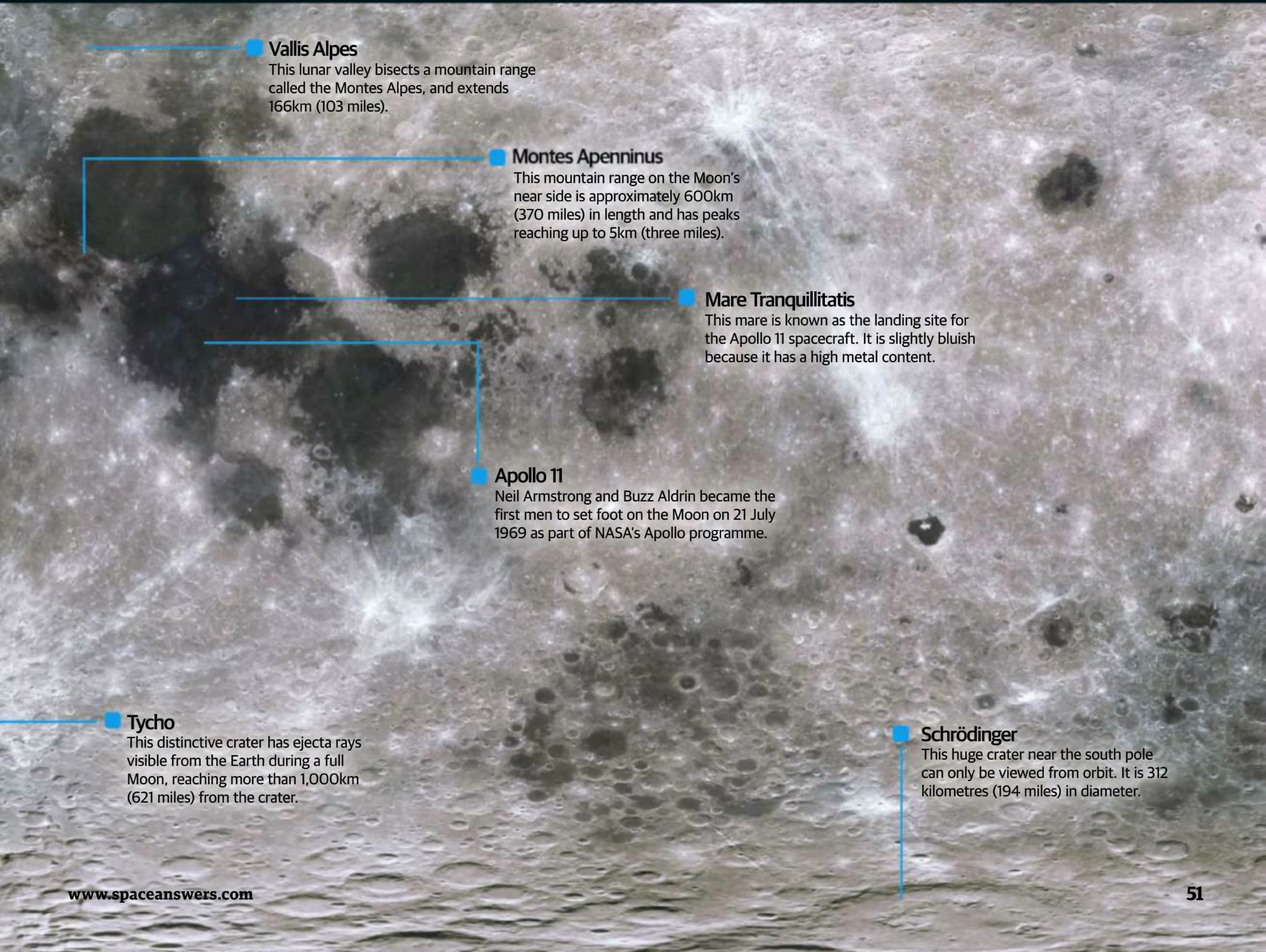
Copernicus
This crater is well known because it can be easily seen from the Earth. It is a younger crater (about 800 million years old) with a prominent system of ejecta rays.

impacts from meteors, as well as space weathering (solar wind, cosmic rays, meteorite bombardment and other processes), break down the rocks and grind them into dust. Aside from the basalt and anorthosite rocks, there are also impact breccias – rock fragments that were welded together by meteor impacts – and glass globules from volcanic activity.

Although you may see the term 'lunar atmosphere' used in some places, the Moon is actually considered to exist in a vacuum. There are particles suspended above the surface, but the density of the Moon's atmosphere is less than one hundred trillionth that of the Earth's atmosphere. What little atmosphere there is gets quickly lost to outer space, and is constantly replenished. Two processes help to replenish the Moon's atmosphere: sputtering and outgassing. Sputtering occurs when sunlight, solar wind and meteors bombard the surface and eject particles. Outgassing comes from the radioactive decay of minerals in the crust and mantles, which can release gases like radon.

This rover travelled across the Moon's surface as part of the Apollo 17 mission in 1972

The Moon has a very minor axial tilt, so there aren't seasons in the same way that we have them here on Earth. However, temperatures on the Moon can change dramatically because there's no atmosphere to trap heat, and portions of the Moon may be either in full sunlight or total darkness depending on where it is in its rotation. Full sunlight can mean temperatures of greater than 100 degrees Celsius (212 degrees Fahrenheit). But at the end of the lunar day, the temperature can drop by hundreds of degrees. There are also big differences in temperatures depending on the surface features. For example, the Moon is coldest in its deepest craters, which always remain in darkness. The coldest temperature ever recorded in the Solar System by a spacecraft was measured by the Lunar Reconnaissance Orbiter in the Hermite Crater near the Moon's north pole at -248 degrees Celsius (-414 degrees Fahrenheit). ■



Vallis Alpes
This lunar valley bisects a mountain range called the Montes Alpes, and extends 166km (103 miles).

Montes Apenninus
This mountain range on the Moon's near side is approximately 600km (370 miles) in length and has peaks reaching up to 5km (three miles).

Mare Tranquillitatis
This mare is known as the landing site for the Apollo 11 spacecraft. It is slightly bluish because it has a high metal content.

Apollo 11
Neil Armstrong and Buzz Aldrin became the first men to set foot on the Moon on 21 July 1969 as part of NASA's Apollo programme.

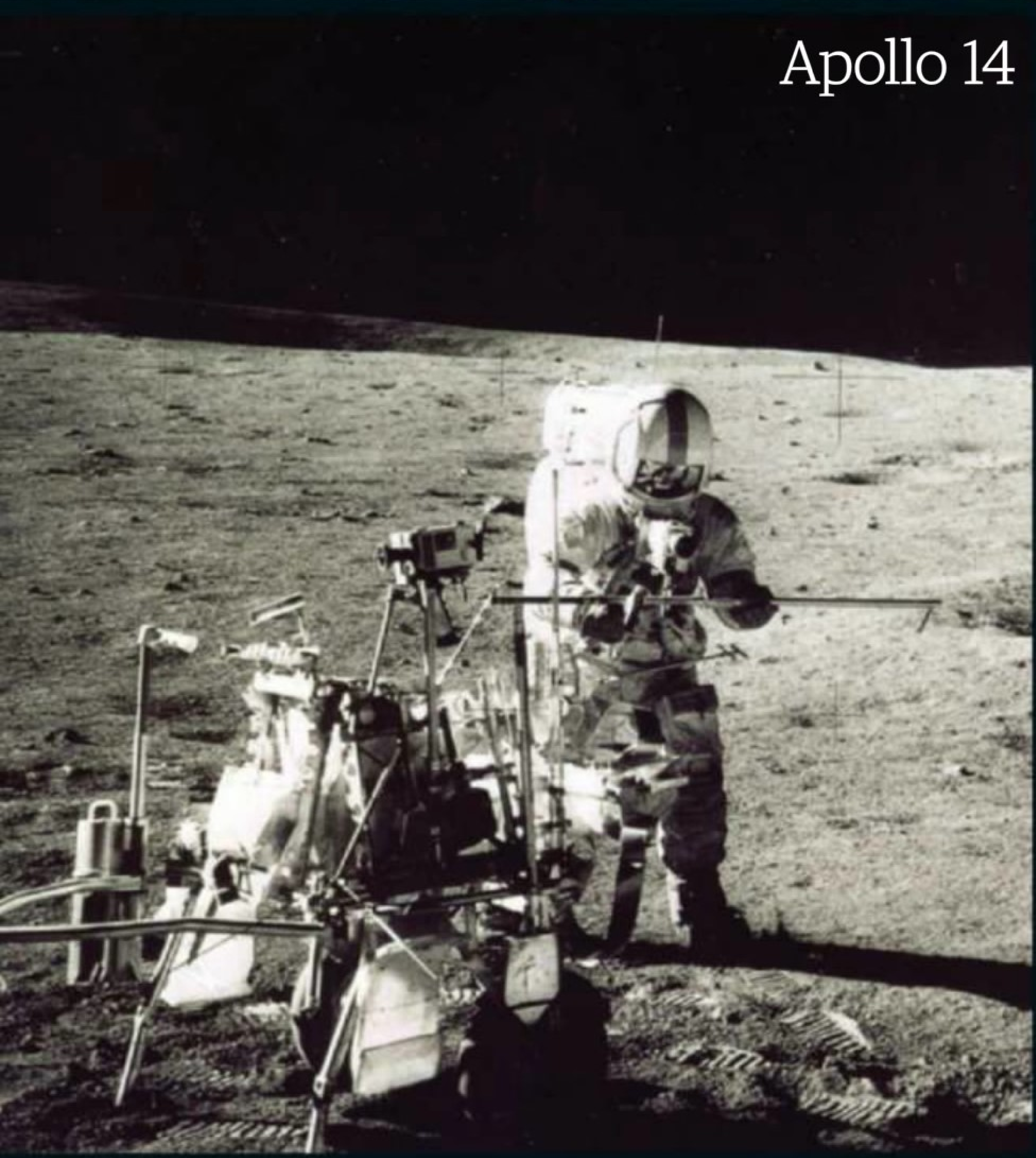
Tycho
This distinctive crater has ejecta rays visible from the Earth during a full Moon, reaching more than 1,000km (621 miles) from the crater.

Schrödinger
This huge crater near the south pole can only be viewed from orbit. It is 312 kilometres (194 miles) in diameter.

Apollo 11

Apollo 12

Exploring the Moon – The Past



Apollo 14

Apollo 11 21 July 1969
NASA astronauts Buzz Aldrin and Neil Armstrong became the first humans to set foot on another body in space when they landed on the Moon in 1969. This mission ended the race to the Moon between the United States and the USSR.

Apollo 12 19 November 1969
The second spacecraft to land on the Moon, Apollo 12 used a Doppler effect radar technique to precisely land the spacecraft within walking distance of the Surveyor 3 probe, which had landed on the lunar surface about two years prior.

Apollo 145 February 1971
The commander on board the third spacecraft to land on the Moon was Alan Shepard, who, a decade earlier on 5 May 1961, had become the second person in space after Yuri Gagarin and the first American as part of the Mercury programme.

Apollo 15 30 July 1971
NASA deemed this Moon landing the most successful so far out of its manned missions. It is also known as the first of the longer missions to the Moon, called 'J missions', staying for three days.

Apollo 16 21 April 1972
Apollo 16 became the first spacecraft to land in the highlands on the Moon, which let them gather older lunar rocks. The astronauts also spent about three days on the surface.

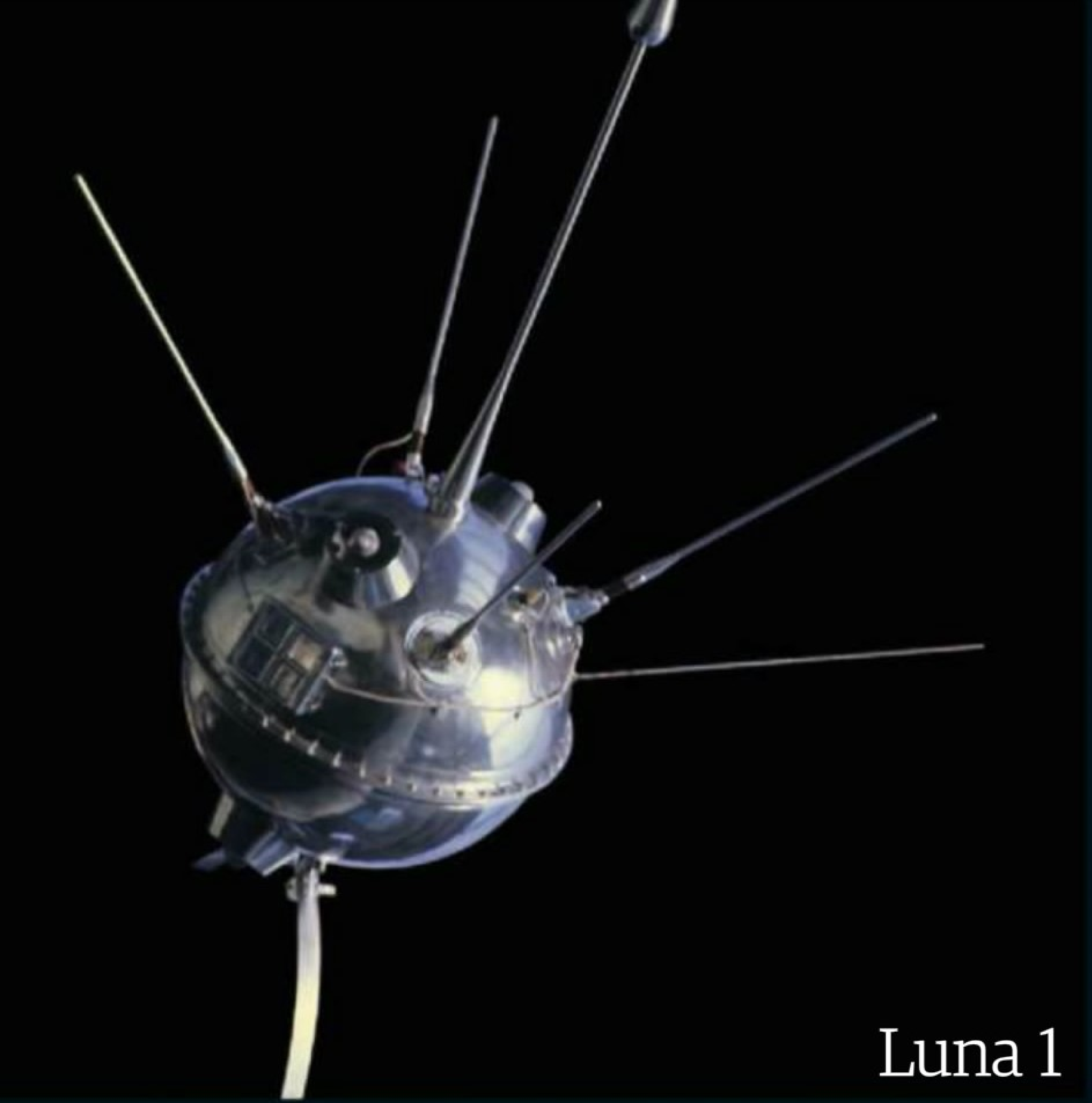
Apollo 17 11 December 1972
This last manned mission to the Moon was the only one to carry the Traverse Gravimeter Experiment (TGE) that measured relative gravity at different sites on the Moon.

Luna 1 4 January 1959
This Soviet probe was the first to reach the vicinity of the Moon and the first to break out of geocentric orbit, however, it did not actually impact the Moon as had originally been planned.

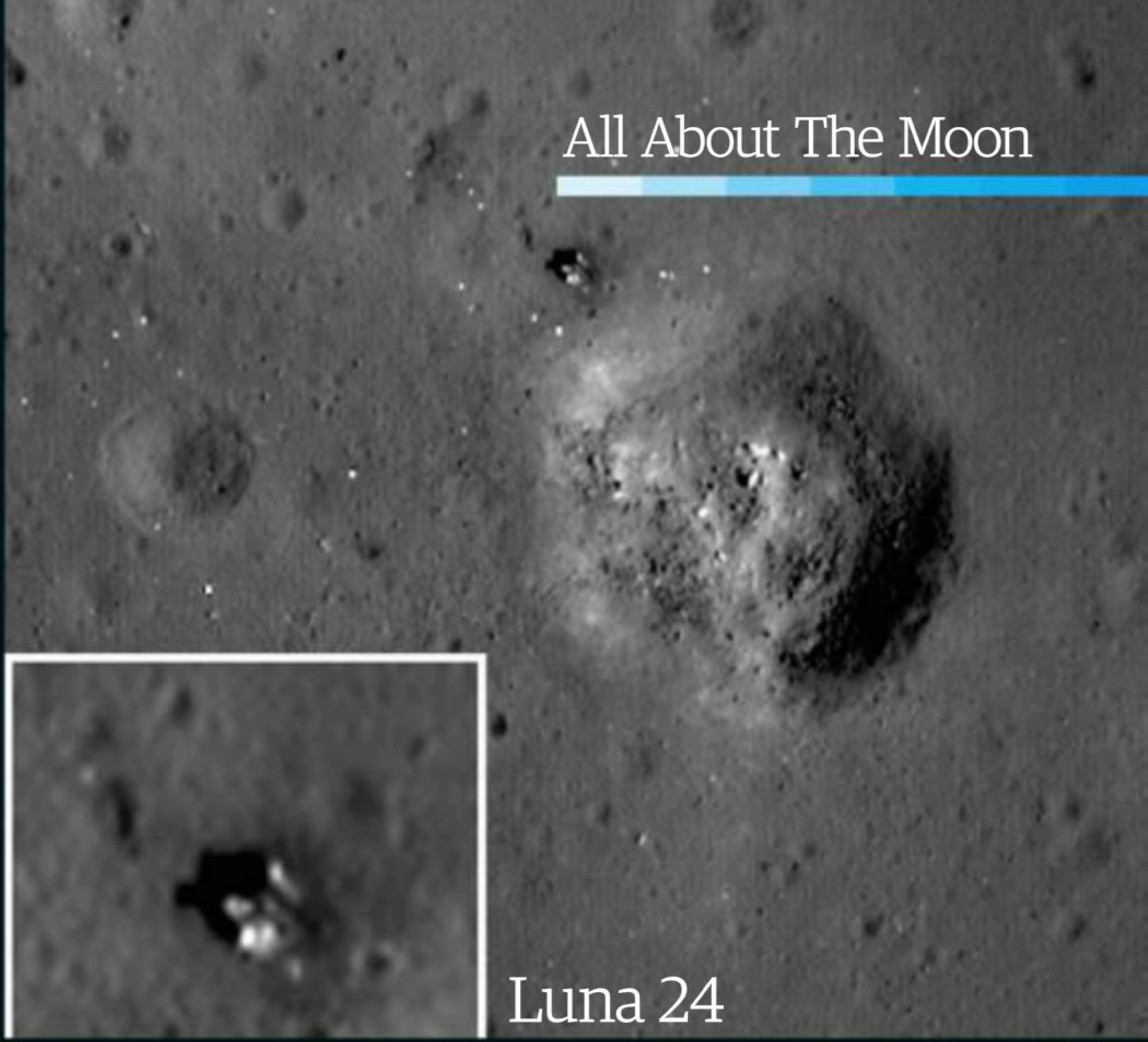
Luna 21 15 January 1973
This Soviet spacecraft landed on the Moon and carried a lunar rover, Lunokhod 2. It performed numerous experiments and sent back more than 80,000 images before failing.

Luna 24 22 August 1976
This was the last of the Luna missions, successfully landing near Mare Crisium to recover samples. It remains the last spacecraft to have a soft landing on the Moon's surface.

Apollo 15

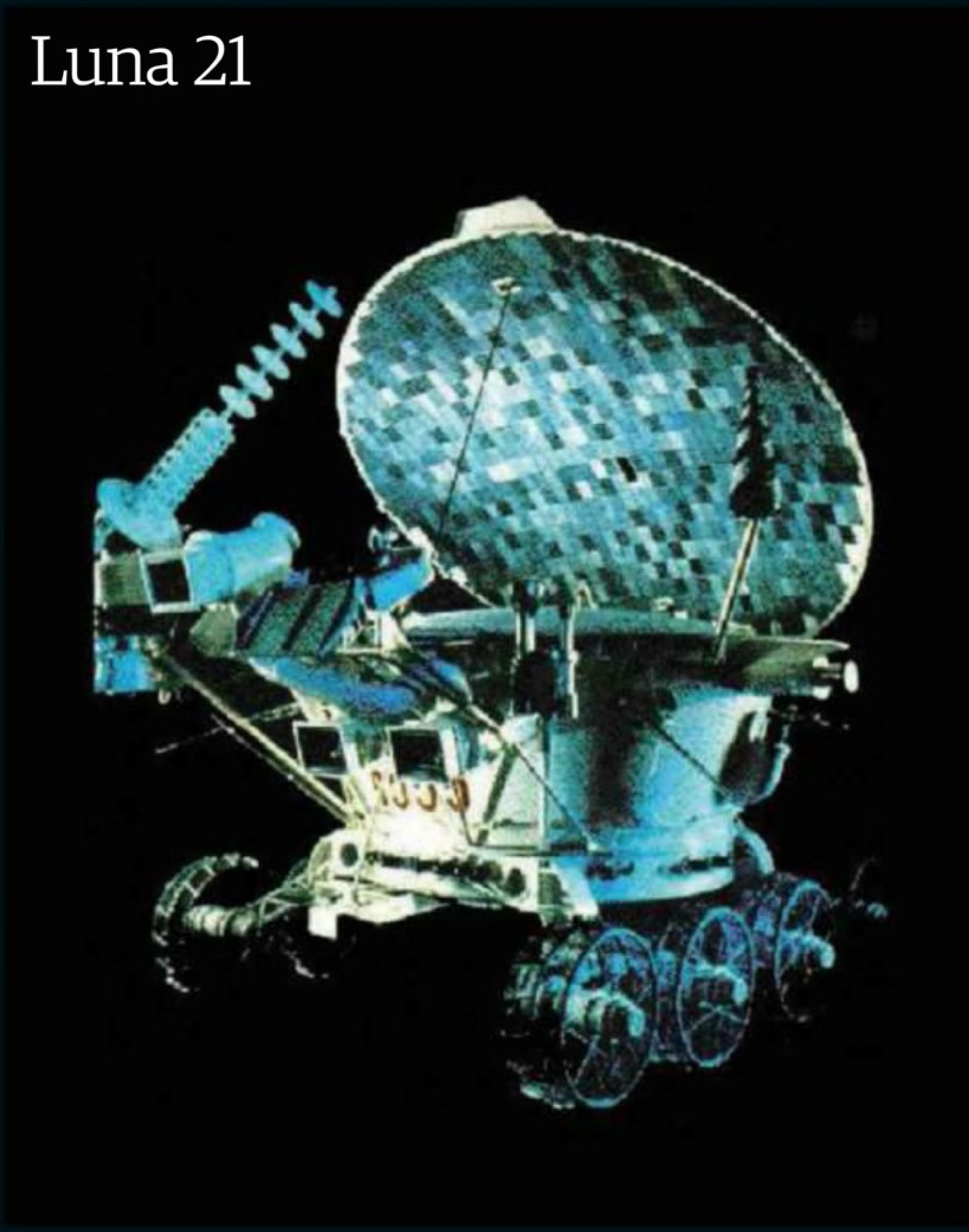


Luna 1



Luna 24

Apollo 16



Luna 21

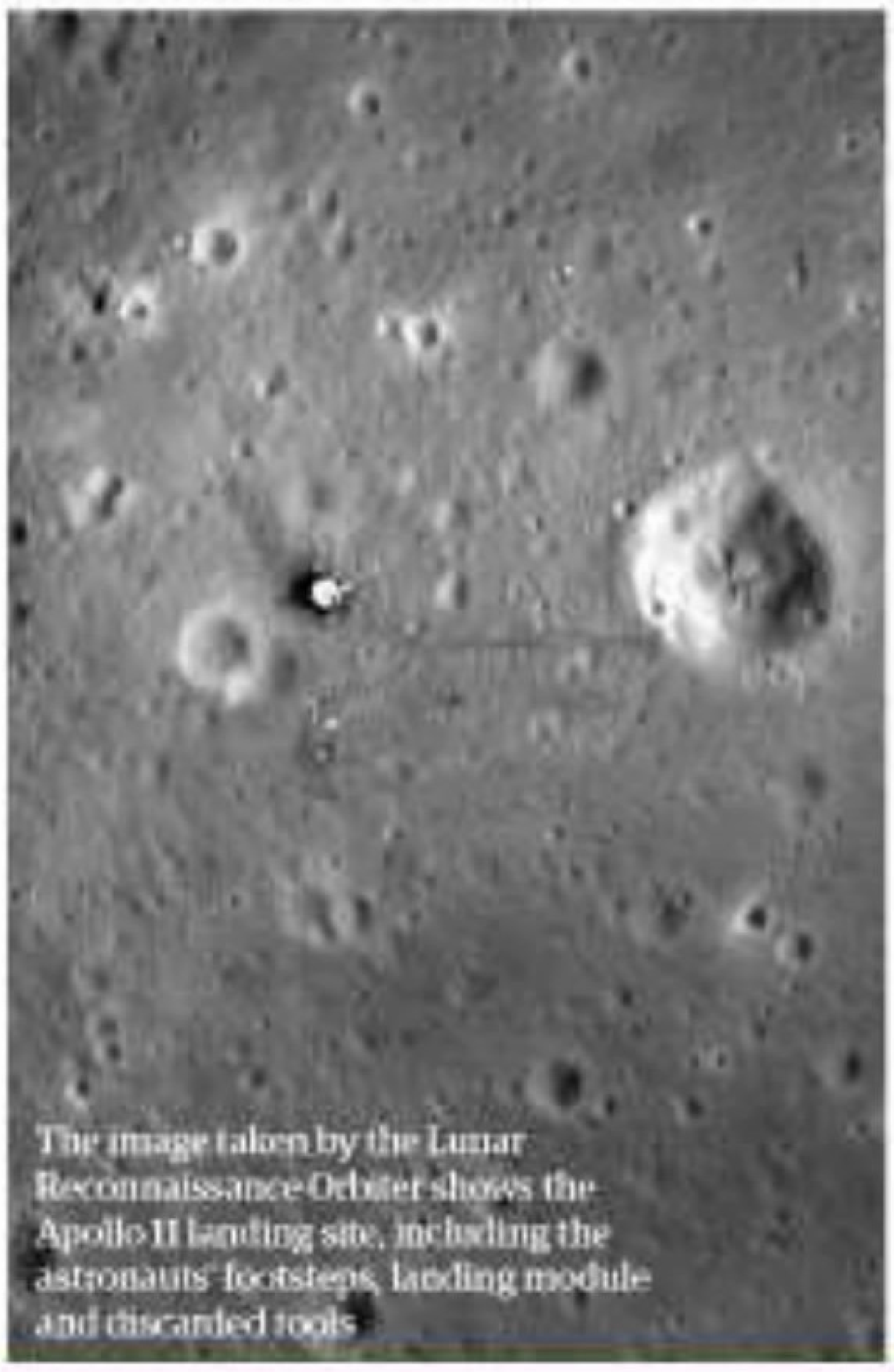
Apollo 17

Exploring the Moon – Present and future

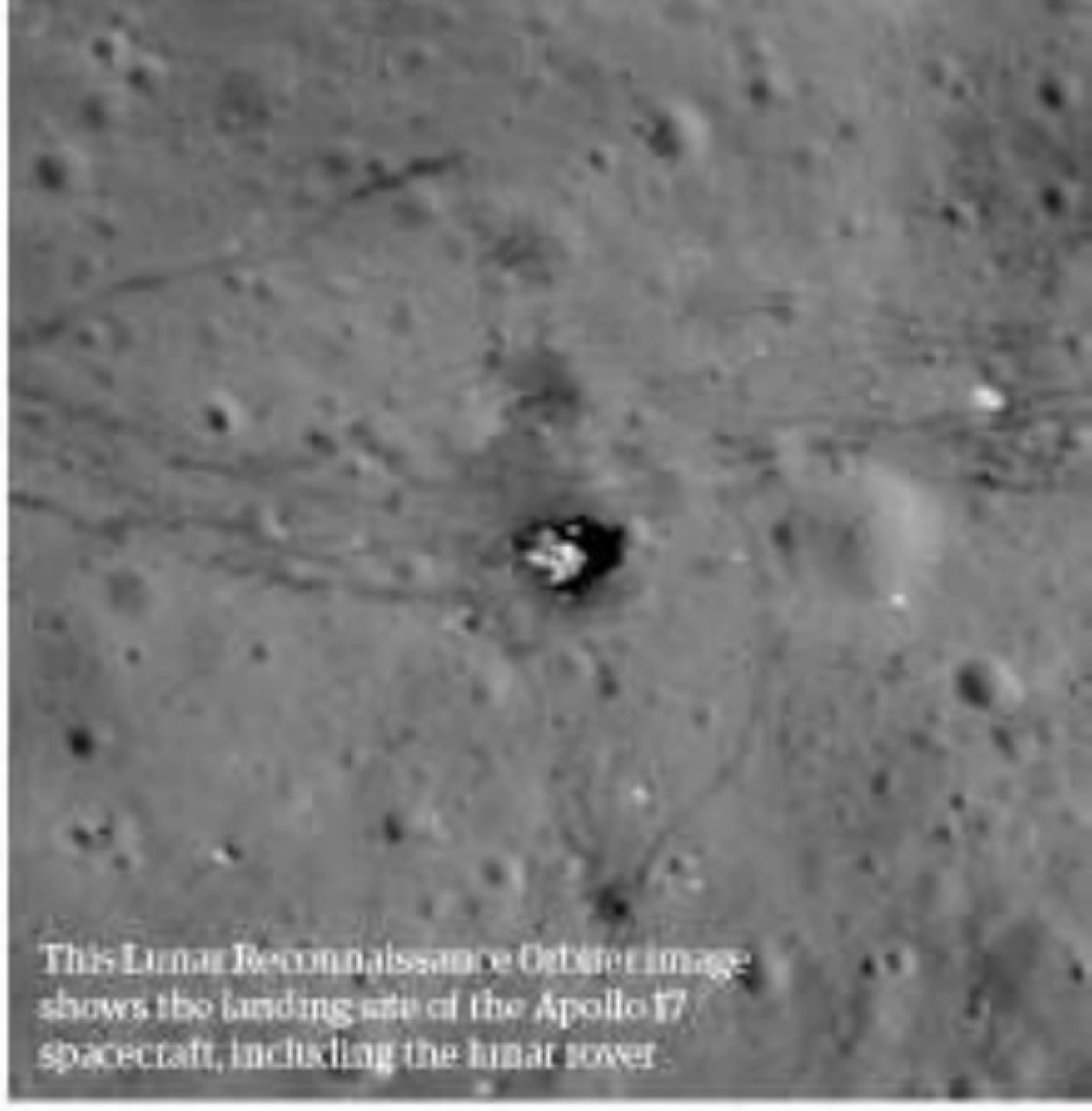
We've been studying the Moon for over 50 years, and thanks to a host of pioneering missions we now know more about our satellite than ever before

Although there hasn't been a manned mission to the Moon since 1972 and there were no soft landings at all until 1966, we're still exploring our satellite. Currently the Lunar Reconnaissance Orbiter (LRO) is still circling the Moon. It launched on 18 June 2009, and became the first NASA mission to the Moon in more than a decade. The LRO is meant to be a precursor to future manned missions, and was originally designed to spend just a year in orbit. However, the mission was extended several times. It was designed to extensively map the Moon in high resolution, explore the potential of ice in the polar regions, study the deep space radiation, and continue to map the surface of the Moon. The other current NASA mission is ARTEMIS, an extension of an earlier satellite mission. Two small probes have been orbiting the Moon together since summer 2011, having previously performed lunar and Earth flybys.

The Lunar Crater Observation and Sensing Satellite (LCROSS) was launched along with the LRO and considered an inexpensive way to look for water ice, and it was successful. The LCROSS discovered ice in the Cabeus crater near the Moon's south pole after its upper stage impacted as planned on 9 October 2009. Two small spacecraft under the name GRAIL A and GRAIL B were launched on 10 September 2011 and impacted on 17 December 2012, having collected data to help understand how terrestrial planets have evolved. Japan, India and China have all had lunar probes in the last six years as well. Currently there are several proposed lunar missions on the table for launch within the next few years, coming from the United States, China, Russia and India. ●


The image taken by the Lunar Reconnaissance Orbiter shows the Apollo 11 landing site, including the astronauts' footsteps, landing module and discarded tools

> "It was designed to extensively map the Moon in high resolution"


This Lunar Reconnaissance Orbiter image shows the landing site of the Apollo 17 spacecraft, including the lunar rover

Buzz Aldrin and Neil Armstrong became the first humans to walk on the Moon in 1969

The Lunar Reconnaissance Orbiter captured this image of a recent impact in the Oceanus Procellarum, which deposited a huge ejecta blanket

Current and future missions

Luna-Glob
Russia

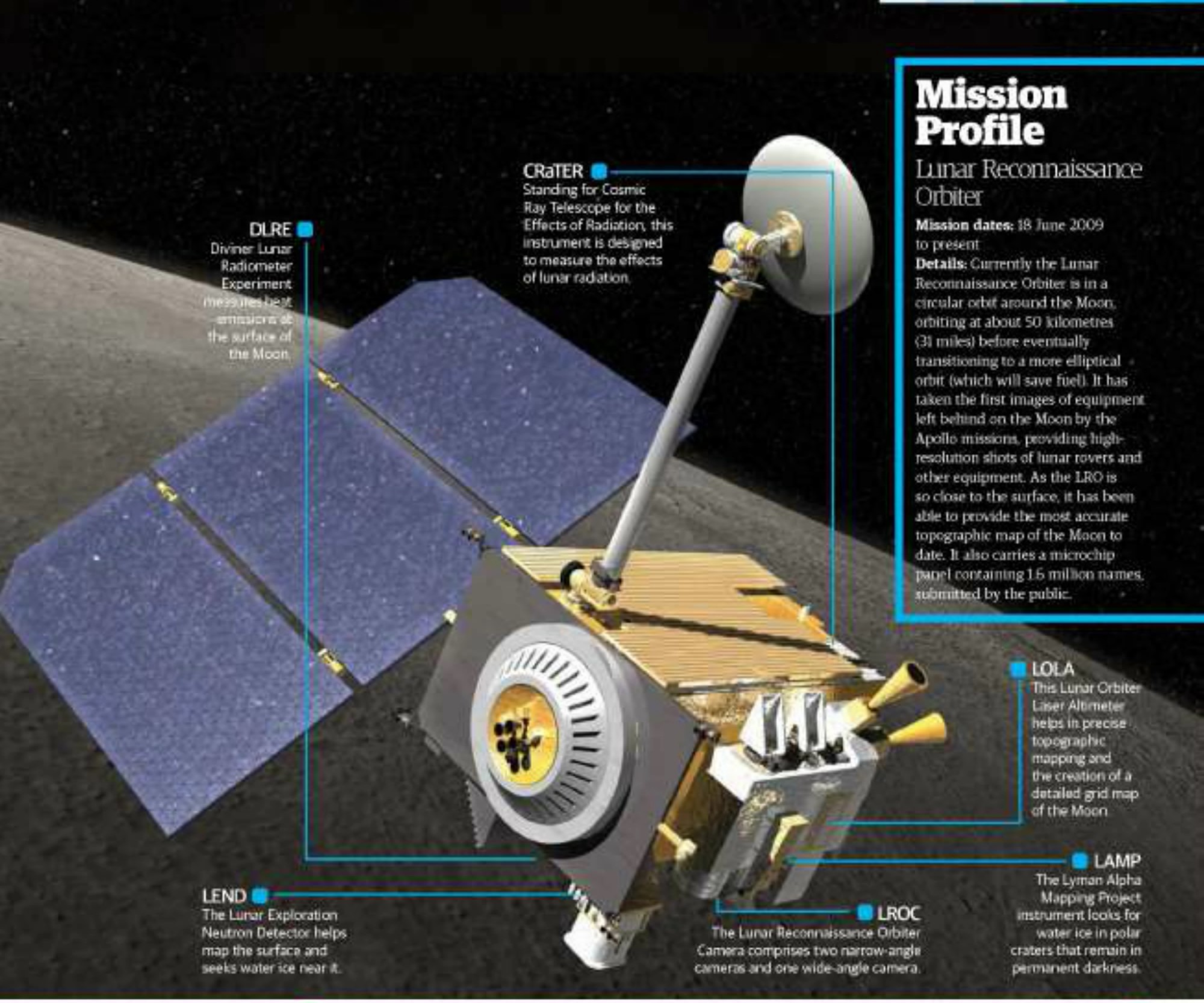
This Russian Federal Space Agency programme is scheduled to be the first of a series of missions, with the ultimate goal of creating a robotic base on the Moon. Its goals include gathering seismic activity, studying cosmic rays, and studying the origin of the Moon.

Chang'e 2
China

This Chinese probe was launched on 1 October 2010 and left lunar orbit in November to go on an extended mission. Chang'e 2 was designed to study future landing sites.

Kaguya
Japan

Also known as SELENE, this Japanese orbiter was launched on 14 September 2007 and circled the Moon before impacting on 10 June 2009. Kaguya measured the Moon's gravity, studied the surface and sought information on the Moon's history.



DLRE
Diviner Lunar Radiometer Experiment measures heat emissions at the surface of the Moon.

CRaTER
Standing for Cosmic Ray Telescope for the Effects of Radiation, this instrument is designed to measure the effects of lunar radiation.

LOLA
This Lunar Orbiter Laser Altimeter helps in precise topographic mapping and the creation of a detailed grid map of the Moon.

LAMP
The Lyman Alpha Mapping Project instrument looks for water ice in polar craters that remain in permanent darkness.

LROC
The Lunar Reconnaissance Orbiter Camera comprises two narrow-angle cameras and one wide-angle camera.

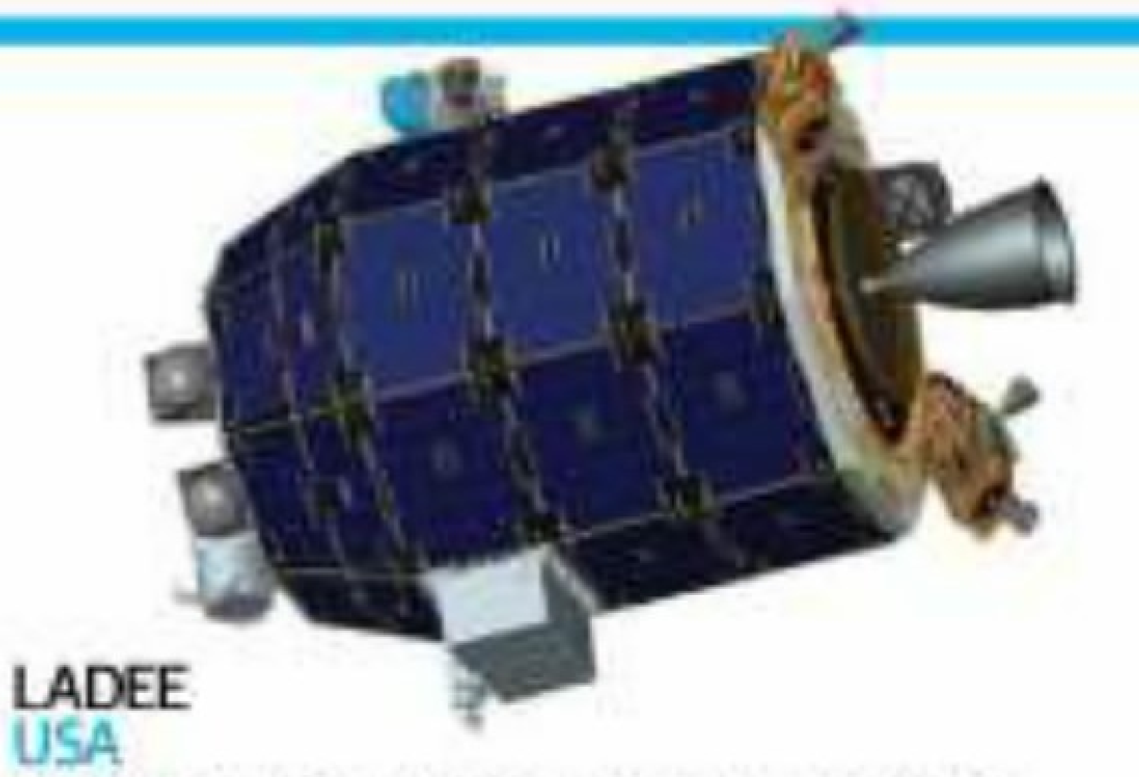
LEND
The Lunar Exploration Neutron Detector helps map the surface and seeks water ice near it.

Mission Profile

Lunar Reconnaissance Orbiter

Mission dates: 18 June 2009 to present

Details: Currently the Lunar Reconnaissance Orbiter is in a circular orbit around the Moon, orbiting at about 50 kilometres (31 miles) before eventually transitioning to a more elliptical orbit (which will save fuel). It has taken the first images of equipment left behind on the Moon by the Apollo missions, providing high-resolution shots of lunar rovers and other equipment. As the LRO is so close to the surface, it has been able to provide the most accurate topographic map of the Moon to date. It also carries a microchip panel containing 1.6 million names, submitted by the public.



LADEE
USA

NASA plans to launch the Lunar Atmosphere and Dust Environment Explorer (LADEE) in August 2013. It hopes to learn more about the lunar atmosphere before there are more manned missions, including the dust on the Moon's surface.

Aurora
Europe

Aurora is the European Space Agency's programme to reach the Moon, Mars and the rest of the Solar System. It is currently in the assessment phase, expected to last until 2015. A manned mission to the Moon would not occur until 2020, after robotic missions to Mars.

Chandrayaan-1
India

This was India's very first unmanned space probe. It launched on 22 October 2008 and the mission ended on 29 August 2009. It launched an impact probe that planted an Indian flag on the south pole, making it the fourth country to place a flag on the Moon.

© NASA; SPL; JAXA/SELENE; [illegible]

Teleportation

It sounds impossible but scientists are working on devices to teleport energy and matter that could eventually revolutionise communication, data transfer and transportation over vast distances

American writer Charles Fort coined the word teleportation in 1931, to describe the sudden disappearance and appearance of objects due to some form of paranormal activity. The idea was taken up by science-fiction writers and was popularised in the Sixties when the *Star Trek* television series featured matter-energy transporters that could instantly send people between planets and spacecraft.

Only four years after Fort's christening of teleportation, the foundation of its creation in reality came about when the EPR paradox was studied by Albert Einstein, Boris Podolsky and Nathan Rosen. They were critical of Niels Bohr's quantum theories, and showed that according to the rules of special relativity the paradox is either impossible or that Bohr's concepts were incomplete.

The EPR paradox concerns the fact that two particles when formed in the same place and time are linked by an invisible force, and share the same existence. When the state of one particle is changed the other particle will also instantly change, even if they are separated by a great distance. What Einstein dismissed as "spooky action at a distance" is now known as quantum entanglement.

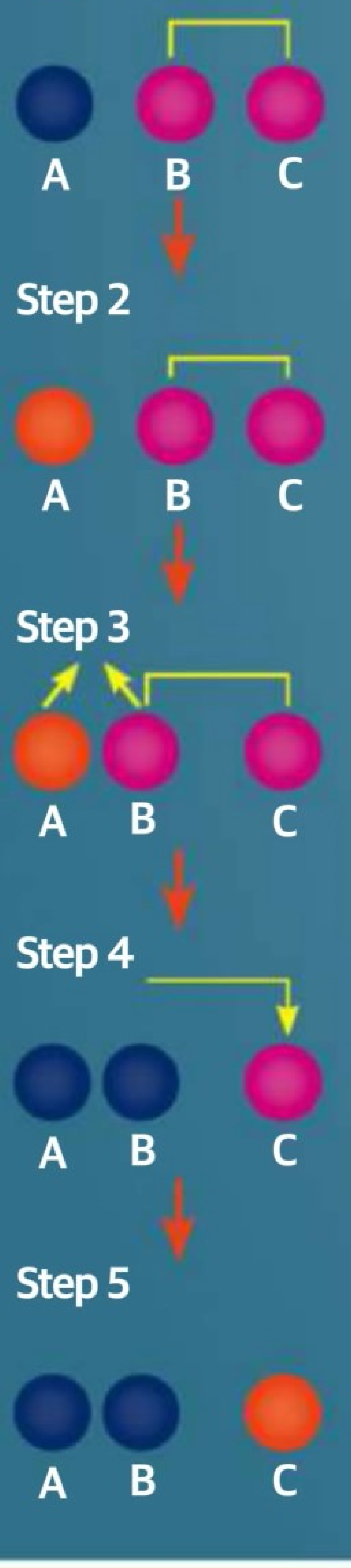
CERN physicist John Bell resolved the paradox in 1964; he labelled it as a 'nonlocal' aspect of quantum physics, which is different from conventional physics known as local realism.

Entanglement of paired photons has been used in experiments that have huge implications for future communication systems and networks. Thomas Jennewein at the University of Waterloo in Ontario, for example, suggests using Earth-orbiting satellites that could create and beam down millions of entangled photons to two ground reception stations. The ground stations would compare the communication signals and if they are not identical they will know that they have been intercepted. This system enables the signals to travel further in the vacuum of space, than via fibre optic cables, and they provide ultra secure encryption for sensitive data and transactions.

Jian-Wei Pan of the University of Science and Technology of China (USTC) has also experimented with paired photons. He has sent teleported photons along a laser beam to a detector 97 kilometres (60 miles) away. There are now plans to launch a satellite in 2016 to carry out quantum experiments, and to pave the way for a global communications network that will use entangled multiple quantum bits (qubits) to transmit at high speed to powerful quantum computers.

Entangled photons are easy to transmit, but they are not easy to store. In contrast, larger ions and atoms are harder to transmit but preserve entanglement for longer. Work is progressing rapidly throughout the world to perfect the methods of creating and transmitting data and energy using quantum entanglement, but we are still a long way from beaming up solid objects and people. ■

Quantum teleportation



Step 1

Entanglement generation
Two atoms (B and C) are entangled to create a pairing connected by an invisible wave.

Step 2

Preparation
The state of the atom's energy, motion or magnetic field is created in a third atom (A).

Step 3

Joint measurement
One of the paired atoms, in this case B, is entangled with atom A, and both are measured.

Step 4

Conditional transformation
Atom C receives the result of the measurement, over any distance.

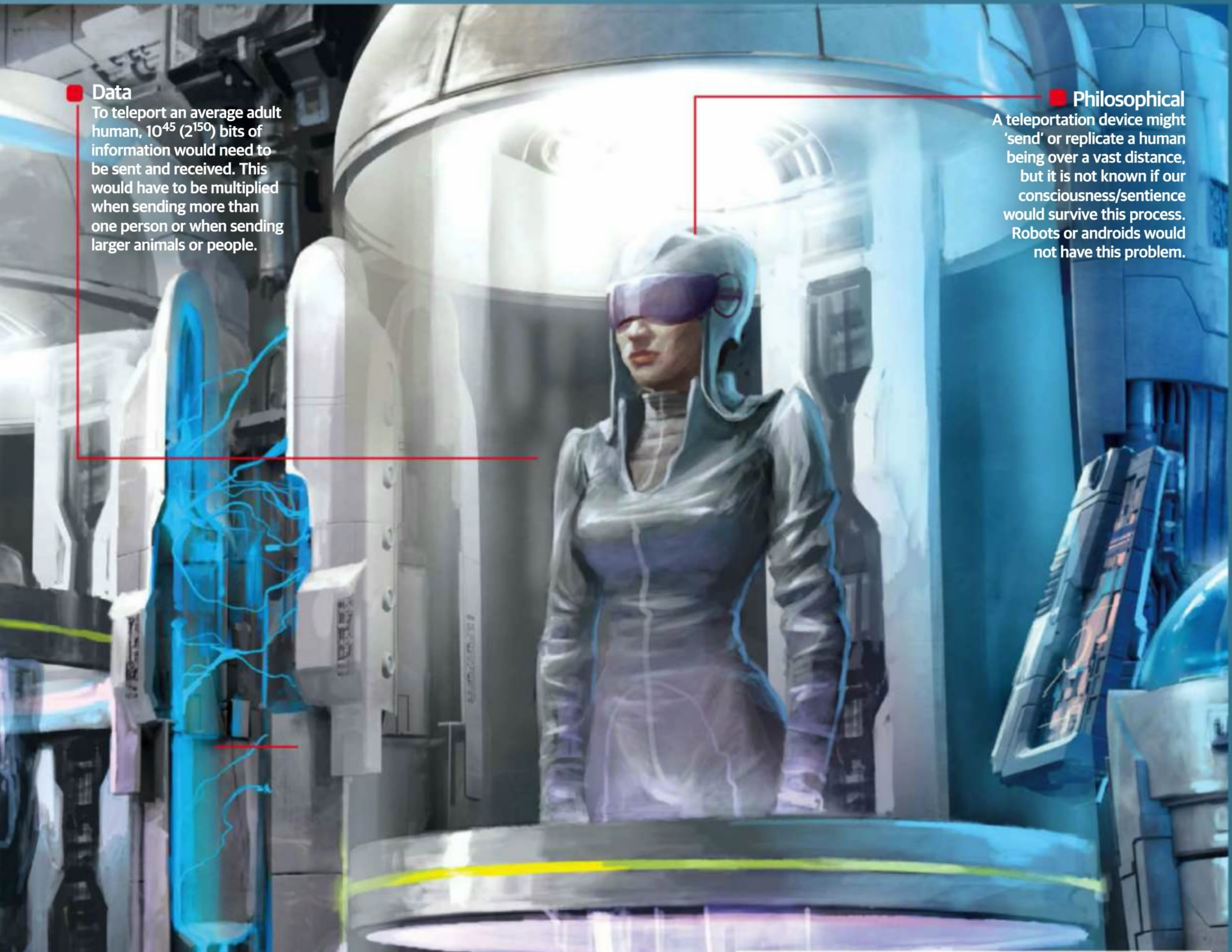
Step 5

Teleportation
In milliseconds, atom C changes into the same state as A, and simultaneously destroys the quantum state of A.

Receiving station
Spaceships would have to deliver teleportation receiving stations to distant planets or star systems to establish a teleportation network that would make space exploration and colonisation faster and easier.

Living matter
So far, only information and energy have been teleported over relatively short distances. Teleporting living organisms is far more complex and dangerous.

Beam me up
Quantum teleportation is one small step towards the dream of beaming living beings instantly over any distance.

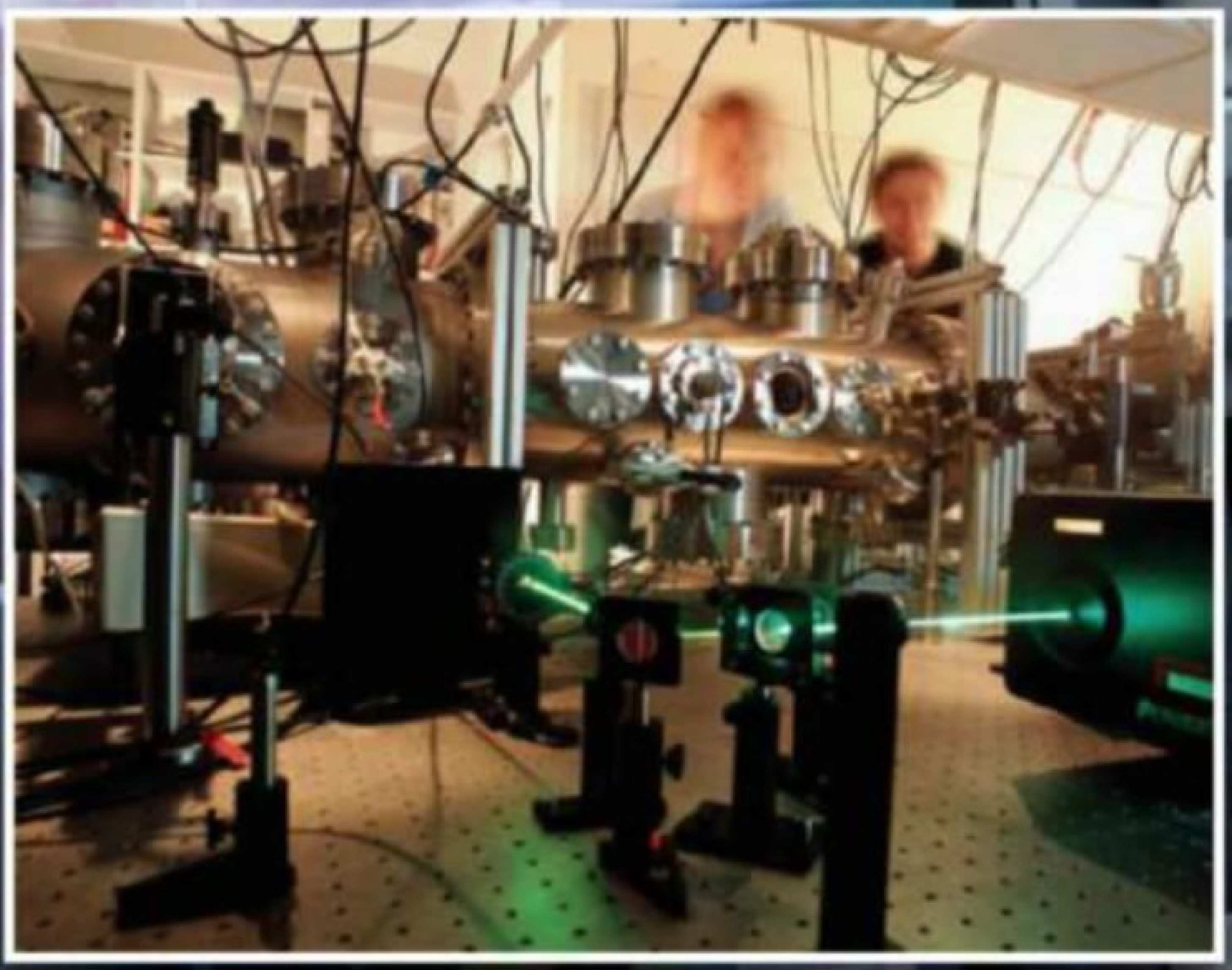


Data

To teleport an average adult human, 10^{45} (2^{150}) bits of information would need to be sent and received. This would have to be multiplied when sending more than one person or when sending larger animals or people.

Philosophical

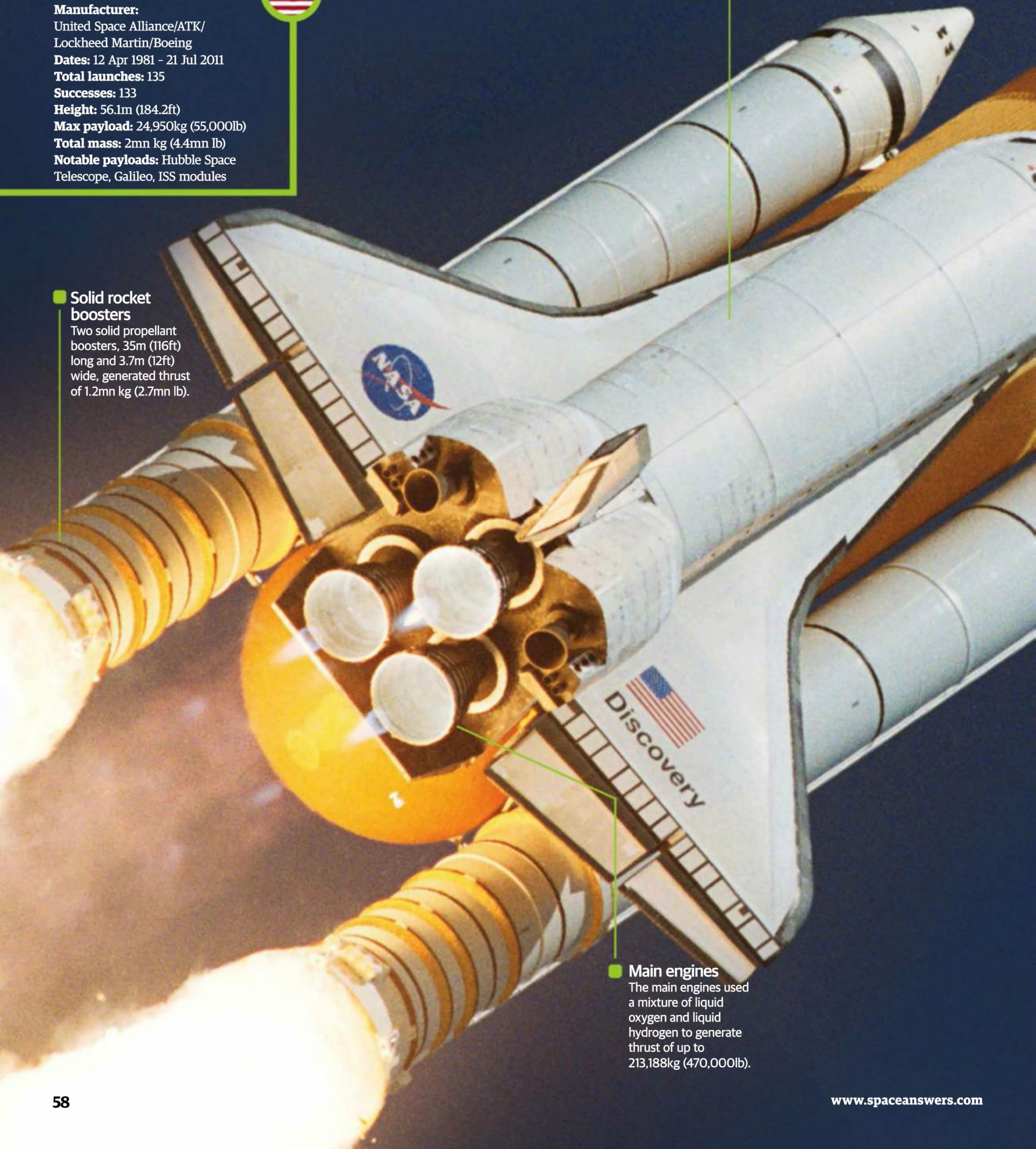
A teleportation device might 'send' or replicate a human being over a vast distance, but it is not known if our consciousness/sentience would survive this process. Robots or androids would not have this problem.



Quantum entanglement equipment is used at Vienna University, Austria, to prove that when a particle is changed its entangled particle will also change, irrespective of how far away it is

© SPL; Jay Wong

Manufacturer:
United Space Alliance/ATK/
Lockheed Martin/Boeing
Dates: 12 Apr 1981 – 21 Jul 2011
Total launches: 135
Successes: 133
Height: 56.1m (184.2ft)
Max payload: 24,950kg (55,000lb)
Total mass: 2mn kg (4.4mn lb)
Notable payloads: Hubble Space Telescope, Galileo, ISS modules



Orbiter
Each orbiter was 37m (121ft) long with a wingspan of 24m (78ft) and a tail height of 17m (57ft).

Solid rocket boosters
Two solid propellant boosters, 35m (116ft) long and 3.7m (12ft) wide, generated thrust of 1.2mn kg (2.7mn lb).

Main engines
The main engines used a mixture of liquid oxygen and liquid hydrogen to generate thrust of up to 213,188kg (470,000lb).

10 AMAZING SPACE ROCKETS

Written by Jonathan O'Callaghan

We take a look at the biggest, best and most prolific launch vehicles to have reached space, from the early days of space exploration through to the present day

Crew quarters
The crew were housed in the front of the orbiter, the payload in the middle and the engines in the aft.

External tank
The external tank, for fuel storage, was 47m (154ft) long and 8.7m (28.5ft) wide; it was the only part of the STS that wasn't reused.

1 Space Shuttle

reusable launch system

The Space Shuttle remains one of the most controversial spacecraft ever flown. While its awesome power and practical reusability were plain for all to see, a high cost and two devastating tragedies meant it was constantly under criticism. When the Shuttle programme, officially called the Space Transportation System (STS), was stopped in 2011 it was therefore met with a mixture of sadness at seeing the vehicle retired but also optimism for a new safer era of launchers.

Conceived in the Sixties and Seventies as a means to reach space regularly and reasonably, the Space Shuttle was in reality blighted by budget overruns and delays. When operational flights began in 1982 it was already proving expensive, but NASA made the most of the situation and cemented the Space Shuttle as its primary method of taking humans, cargo, satellites, probes and more into orbit.

This launcher was unique. Two solid rocket boosters were strapped to a central fuel tank, which worked in tandem with engines on the orbiter itself to get the vehicle to its lofty destination. While the main fuel tank was discarded in the upper atmosphere, the solid rocket boosters were recovered from the ocean to be used again – one of the first instances of rocket reusability. Of course, the orbiter itself was also reused. Six Space Shuttle orbiters were built in total, although one – Enterprise – was only used for testing and never entered space.

Technically, if you count the orbiter as a payload rather than a rocket, then the STS is the closest challenger to the Saturn V for the most powerful rocket ever to have been launched. The maximum takeoff weight of a Shuttle orbiter (including the orbiter, fuel and a payload) was around 109,000 kilograms (240,000 pounds), with about 25,000 kilograms (55,000 pounds) of that taken up by the useful payload. It was capable of taking cargo in its payload bay into low-Earth orbit (LEO), which could then be fired into orbit. It launched a huge number of well-known spacecraft, satellites, probes, telescopes and more. These include the Hubble Space Telescope, the Jupiter-orbiting Galileo spacecraft, and many of the modules for the ISS.

Despite its one-of-a-kind status and unrivalled reusability, the Shuttle's two major failures will always be remembered. On 28 January 1986, Space Shuttle Challenger fell apart just 73 seconds after launch, killing all seven of its crew members. 17 years later Space Shuttle Columbia broke up on re-entry on 1 February 2003, also resulting in the death of its seven-person crew.

These two accidents serve as a constant reminder of the perils of space exploration. While the Space Shuttle completed 133 successful missions, and showed for the first time that humans could travel to space and return in a reusable vehicle capable of landing on a runway, we must never forget the dangers of undertaking such endeavours. ■

Manufacturer: Boeing/United Launch Alliance
Dates: 20 Nov 2003 - present
Total launches: 21
Successes: 21
Height: 63-72m (206-235ft)
Max payload: 23,000kg (50,700lb)
Upper mass: 733,400kg (1.6mn lb)
Notable payloads: Eutelsat W5, USA-202, Orion (scheduled for 2014)

The Delta IV Heavy is the most powerful rocket in use at this time

2 Delta IV

The most powerful rocket operating today

The Delta family of rockets has been one of the mainstays of American space exploration, used since the Sixties to take various governmental and private satellites into orbit. Delta rockets are primarily used by the United States Air Force (USAF), although a Delta IV rocket is due to carry NASA's Orion spacecraft into orbit for the first time in 2014.

The Delta IV is the product of over half a century of upgrades. It employs many of the technologies used in previous Delta rockets, including the main tank and payload fairing, but also boasts advanced capabilities, such as the use of liquid hydrogen fuel in its first stage, which makes it a relatively cheap but reliable option for getting satellites into orbit. Like the Atlas V it is part of the Air Force's EELV (Evolved Expendable Launch Vehicle) programme, and thus the rocket is discarded after takeoff.

While most Delta IV rockets fall into the 'medium' category for rockets, a larger and more powerful version known as the Delta IV Heavy has come into use in the last decade. First launched in 2004, the Heavy is capable of taking much bigger satellites – and more of them – into orbit. It has five fully successful launches under its belt, and one partial success. It is very similar to the Delta IV, but it has two additional boosters on the side that allow it to gain an increase in thrust. The Delta IV Heavy is the most powerful rocket currently in service today, and the most powerful since the Saturn V. ■

3 Long March 2F

The rocket launching China's new era of space exploration

The Long March family of rockets has been China's main means to reach the cosmos since its space programme stepped up a gear in the Nineties. The first flight of the upgraded Long March 2F was an unmanned test of the Shenzhou spacecraft in 1999, with the first manned flight four years later.

The Long March 2F has an enviable 100 per cent launch record, and in the past couple of years it was used to take up China's first orbital space station, Tiangong-1, as well as fly crew members there.

Around the central core of the rocket are four strap-on boosters that are discarded en route to orbit, while the core and final stage are dropped higher up. Aside from Russia's Soyuz-FG rocket, the Long March 2F is the only human-rated rocket currently in use.

Unlike previous Chinese rockets, the Long March 2F is the first to be rolled out vertically to the launchpad, like some of its European and American counterparts. It will continue to be used for manned flight for the foreseeable future. ■

The Long March 2F is a human-rated version of the previous Long March 2E

Manufacturer: China Academy of Launch Vehicle Technology (CALT)
Dates: 19 Nov 1999 - present
Total launches: 10
Successes: 10
Height: 62m (203ft)
Max payload: 8,400kg (18,520lb)
Total mass: 464,000kg (1.02mn lb)
Notable payloads: Shenzhou

4

Saturn V

The biggest rocket ever launched

If there is one rocket that elicits the fondest memories of a bygone age of space exploration when manned missions were at the forefront of the public eye, then the Saturn V has to be it. It's often bandied as the world's most powerful rocket, even to this day, but while that's true it's not until you stare at the figures that you realise just how powerful this vehicle really was. By comparison, the world's most powerful rocket currently in operation – the Delta IV Heavy – has only about a quarter of the lifting capability of the Saturn V.

Barring a couple of unsuccessful rockets built by the Soviet Union, the Saturn V remains unchallenged in its status as the biggest rocket to launch to date and will continue to be so until NASA and SpaceX complete the Space Launch System (SLS) and Falcon Heavy rockets, respectively, at some point later this decade or in the early-2020s.

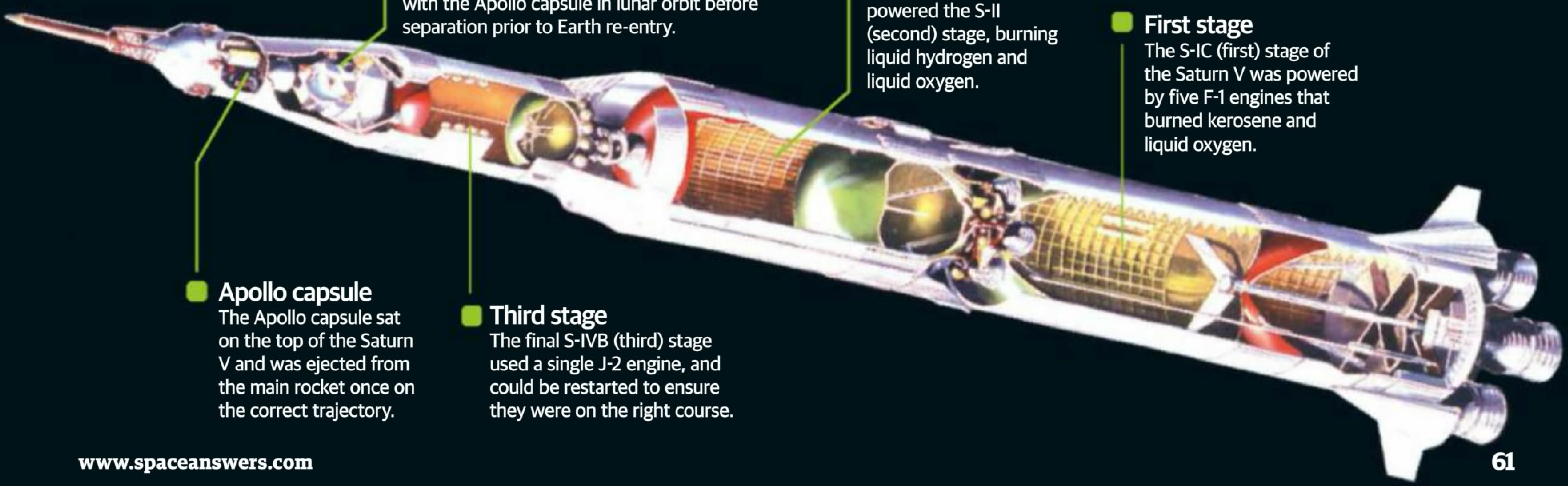
The original Saturn V made 12 launches, all of which were successful (except for one slight mishap during Apollo 6), while a modified 13th Saturn V was used to launch the Skylab space station in 1973. The Saturn V was massive, towering 111 metres (363 feet) high and weighing about 2.8 million kilograms (6.2 million pounds) – that's more than eight Atlas V rockets strapped together! It used a mixture of liquid hydrogen, liquid oxygen and kerosene as its fuel, and comprised three stages.

It was designed by rocket scientist Wernher von Braun, who is widely credited with advancing rocket technology like no one else in the Forties, Fifties and Sixties. Its predecessors were the Jupiter series of rockets and later the Saturn I. The Saturn V remains the only vehicle to have ever taken humans beyond Earth orbit, during the Apollo missions. In total it took 21 people to the Moon – three of them twice – and without it our lunar exploration missions simply wouldn't have been possible.

Manufacturer: Boeing/North American Aviation/Douglas
Dates: 9 Nov 1967 – 14 May 1973
Total launches: 13
Successes: 13
Height: 111m (363ft)
Max payload: 120,000kg (260,000lb)
Total mass: 2.8mn kg (6.2mn lb)
Notable payloads: Apollo, Skylab

Apollo 15 launches on its way to the Moon

Inside the Saturn V



Lunar Module
Apollo astronauts landed on the Moon in the Lunar Module, which then redocked with the Apollo capsule in lunar orbit before separation prior to Earth re-entry.

Second stage
Five J-2 engines powered the S-II (second) stage, burning liquid hydrogen and liquid oxygen.

First stage
The S-IC (first) stage of the Saturn V was powered by five F-1 engines that burned kerosene and liquid oxygen.

Apollo capsule
The Apollo capsule sat on the top of the Saturn V and was ejected from the main rocket once on the correct trajectory.

Third stage
The final S-IVB (third) stage used a single J-2 engine, and could be restarted to ensure they were on the right course.

5 Soyuz-FG

The industry's most frequently used rocket

When it comes to old hands, nothing compares to the Soyuz rocket family. Indeed, they are the most frequently used series of rockets with over 720 launches notched up and counting. Initially it launched the Soviet Union into the Space Race, but now it's used to transport astronauts from all over the world to the International Space Station.

The Soyuz-FG is the variant of this rocket family that is in use today, succeeding the highly successful Soyuz-U. The Soyuz-FG is currently one of only two rockets capable of taking humans into space (the other being China's Long March 2F). It flew for the first time on 20 May 2001 and, 12 years later, continues to perform admirably. Indeed, of its 43 launches, none has ever failed.

Unlike many other rockets, all three stages of the Soyuz-FG use the same type of fuel: in this case, kerosene and liquid oxygen. It has four strap-on boosters around a central core stage, which are jettisoned once their tanks are empty, to lift the vehicle into space. Also, as with all human-rated rockets, it has a launch abort system to carry the crew to safety in the event of a launchpad emergency (although this has never been needed).

The Soyuz-FG is used to launch both manned Soyuz spacecraft and unmanned Progress cargo vehicles to the ISS. From 2014 onwards, however, it is expected that the Soyuz-FG will be replaced by the upgraded Soyuz-2 for launches of both spacecraft.

Soyuz-FG rockets are currently used for manned launches to the ISS

Soyuz rockets are transported sideways and erected at the launch pad

Manufacturer: TsSKB-Progress
Dates: 20 May 2001 - present
Total launches: 43
Successes: 43
Height: 49.5m (162.4ft)
Max payload: 7,100kg (15,600lb)
Total mass: 305,000kg (672,000lb)
Notable payloads: Soyuz, Progress

6

Proton-M

Meet Russia's heavy-lift specialist rocket

In operation from 1965 until the present day, the Proton series of rockets remains one of the most successful heavy launch vehicles ever built. These unmanned rockets were designed for commercial and governmental launches, and 340 out of their 384 launches have been successful.

The Proton-M is the latest member of the family, coming into service in April 2001 and still in use today. It is mainly used for commercial launches marketed by International Launch Services (ILS), but it might be used to transport some new components to the ISS in the near-future.

In its 12 years of service the Proton-M has racked up 62 successful launches and four partial successes out of a total 68. The rocket has three stages – all of which are discarded after takeoff – while an optional fourth stage can be added to boost the orbit of a satellite (if, say, it needs to reach geostationary orbit). The Proton, like the Soyuz, has been the cornerstone of Russia's space endeavours for many decades, and will continue to be so for years to come.

Manufacturer: Khrunichev
Dates: 7 April 2001 - present
Total launches: 68
Successes: 66
Height: 53m (174ft)
Max payload: 22,000kg (49,000lb)
Total mass: 712,800kg (1.6mn lb)
Notable payloads: Intelsat, Eutelsat

Protons are the third-most flown rockets in history

7 Ariane 5

Europe's number one launch vehicle

In a similar league to the Proton-M, the Ariane 5 is the European workhorse that continues to be used for many high-profile launches, including the Automated Transfer Vehicle (ATV) which resupplies the International Space Station. It is one of the world's most successful heavy-lift launchers, with the ability to take over 20 tons into low-Earth orbit and over ten tons to geostationary transfer orbit.

This launch vehicle was the evolution of the ESA's Ariane rocket family that enabled the agency to lift multiple heavy payloads into space at once. It got off to a shaky start in the late-Nineties, however, when the initial two launches both experienced failures. On the first launch, on 4 June 1996, the rocket self-destructed after 37 seconds. But, thankfully, these early mishaps led to a much more refined design, and since April 2003 it has had 54 consecutive successful launches.

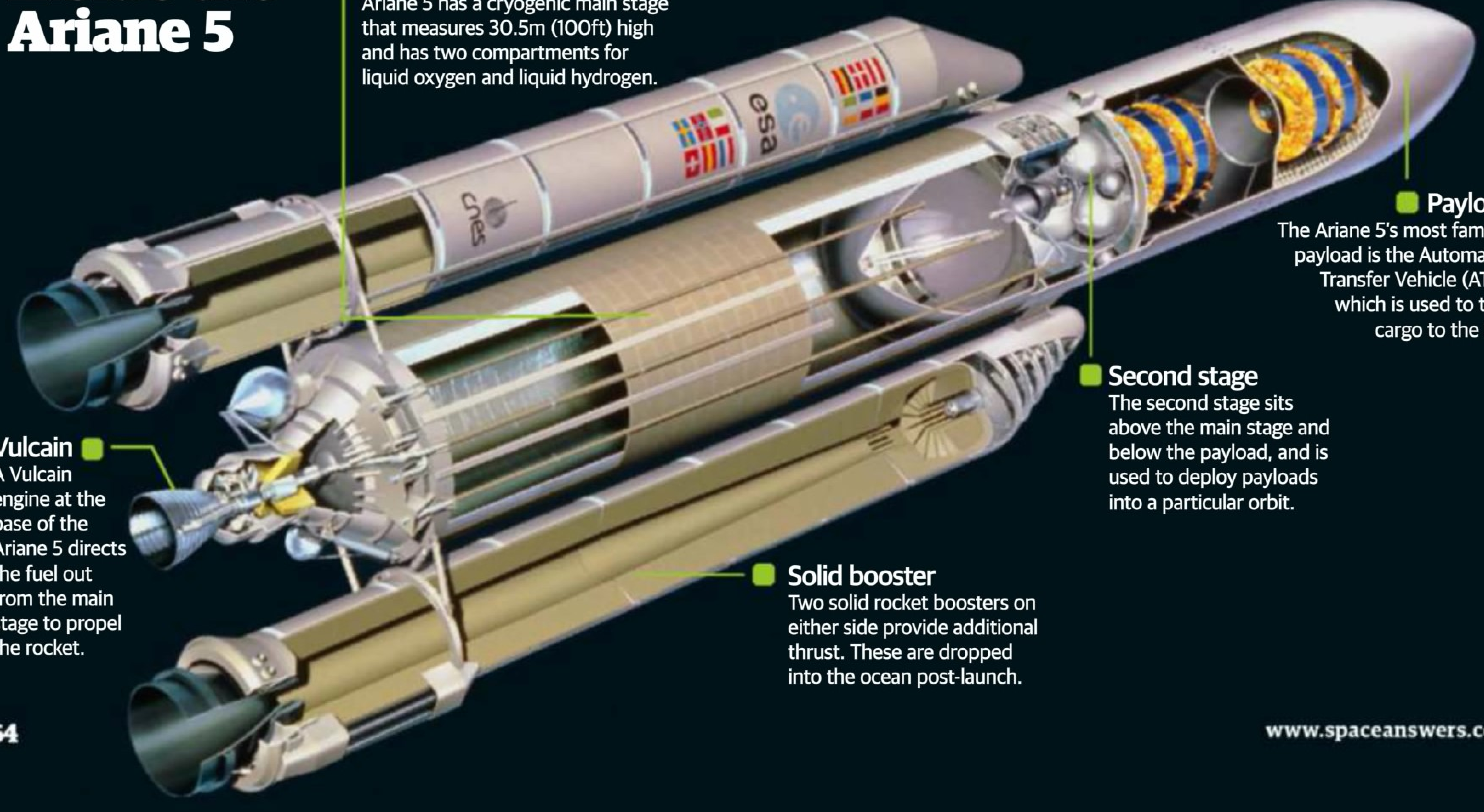
The rocket has a cryogenic main central stage that uses liquid oxygen and liquid hydrogen for fuel. To the sides are two solid rocket boosters that provide additional thrust. After launch the rocket is usually left to fall into the sea, but occasionally the boosters are recovered using parachutes for post-flight analysis, although this is rare.

The Ariane 5 continues to be of huge importance for the ESA, but it will eventually be replaced. The Ariane 5 ME (Mid-life Evolution) aims to reduce launch costs by up to 20 per cent, while the Ariane 6 could be a smaller rocket designed to take single satellites into orbit at a low price. Both will be designed and developed in the coming years.

Ariane 5 will remain in operation until at least 2015

Manufacturer: EADS Astrium
Dates: 4 Jun 1996 - present
Total launches: 68
Successes: 64
Height: 46-52m (151-171ft)
Max payload: 21,000kg (46,300lb)
Total mass: 777,000kg (1.7mn lb)
Notable payloads: Rosetta, ATV, Herschel, Planck

Inside the Ariane 5



Main stage
Ariane 5 has a cryogenic main stage that measures 30.5m (100ft) high and has two compartments for liquid oxygen and liquid hydrogen.

Payload
The Ariane 5's most famous payload is the Automated Transfer Vehicle (ATV), which is used to take cargo to the ISS.

Second stage
The second stage sits above the main stage and below the payload, and is used to deploy payloads into a particular orbit.

Vulcain
A Vulcain engine at the base of the Ariane 5 directs the fuel out from the main stage to propel the rocket.

Solid booster
Two solid rocket boosters on either side provide additional thrust. These are dropped into the ocean post-launch.

8 Atlas V

America's first choice for deep-space missions

As the latest iteration in the Atlas family of rockets – the first of which launched the Mercury astronauts way back in the early-Sixties – the Atlas V has been a massive success over the decades.

Originally operated by Lockheed Martin – and now by the United Launch Alliance – the Atlas V boasts an impressive 100 per cent success record from its 37 launches (although one did experience a minor fault). Since its first launch on 21 August 2002 it has transported various notable payloads into space including the New Horizons probe and the Curiosity rover on Mars, and it continues to be called upon for high-profile launches today.

The Atlas V comes in a variety of configurations that can be altered depending on what type of launch is needed. The rocket can support between one and five solid rocket boosters, with a higher number enabling a heavier payload to be taken into low-Earth orbit (LEO) or beyond. Interestingly, future iterations of the Atlas V may also allow an additional central Centaur stage to be attached to the rocket, which would mean even bigger payloads could be taken into space, such as a manned crew capsule.

Classed as a medium-heavy launch vehicle, the Atlas V stands 58 metres (191 feet) tall on the launchpad and weighs 334,500 kilograms (737,400 pounds) when fully fuelled – which is roughly equivalent to the weight of two adult blue whales.

The largest payload it has ever taken to space was 29,400 kilograms (64,820 pounds), which included the military communications satellite MUOS-1. The Atlas V is known as an Evolved Expendable Launch Vehicle (EELV), which means that none of the rocket is reusable. The solid rocket boosters and core engine are discarded after takeoff. In 2006 it set a record for fastest-ever spacecraft to leave Earth's atmosphere, reaching 57,615 kilometres (35,800 miles) per hour. ●

The Atlas V has never had a launch failure in over ten years of service

The Curiosity Rover is the Atlas V's most famous payload

Manufacturer: United Launch Alliance
Dates: 21 Aug 2002 - present
Total launches: 37
Successes: 37
Height: 58.3m (191.2ft)
Max payload: 29,400kg (64,820lb)
Total mass: 334,500kg (737,400lb)
Notable payloads: MRO, New Horizons, LRO, Juno, MSL Curiosity

9 Titan IV

The workhorse of the American space programme

The Titan family of rockets is perhaps best known for launching the American Project Gemini manned flights during the Space Race in the Sixties. Titan quickly established itself as the workhorse of the US space programme for decades, launching numerous probes into the outer Solar System including the Voyager spacecraft, one of which (Voyager 1) is now at the very boundary of interstellar space.

The later Titan IV became one of the primary rockets used by the US Air Force. Its high level of configurability made it ideal for a wide variety of launches into many different orbits. Its most notable launch was the Cassini-Huygens spacecraft in 1997, which remains in orbit around Saturn today.

Barring a few early failures, the Titan IV had a successful lifetime, completing 35 launches mostly on behalf of the United States Air Force. Ultimately, however, it was rendered obsolete with the arrival of the Atlas V and Delta IV rockets and, as a result, was eventually retired in 2005. ●

Manufacturer: Lockheed Martin
Dates: 14 Jun 1989 – 19 Oct 2005
Total launches: 39
Successes: 35
Height: 61.9m (203ft)
Max payload: 21,680kg (47,790lb)
Total mass: 943,050kg (2mn lb)
Notable payloads: Lacrosse, Cassini-Huygens

Most of Titan IV's launches were for the US Air Force

10 Falcon 9

The first launcher to be backed by a private enterprise

Private spaceflight company SpaceX is trying to shake up the launch vehicle market, designing and developing a new breed of low-cost and potentially reusable rocket that will bring down the cost of taking payloads into orbit. To get there, it is proving its capabilities with the Falcon 9.

The Falcon 9 was the follow-up to the moderately successful Falcon 1 rocket. The latter was SpaceX's first foray into launch vehicles, which achieved its first successful launch in 2008 after three failures, making SpaceX the first company to send a privately funded rocket to orbit.

While the Falcon 1 was more of a demonstration of SpaceX's capabilities, the Falcon 9 is quickly becoming a big player in the launch vehicle market. It has five launches under its belt, with all five proving successful (although one experienced a minor glitch). Its most notable payload has been the Dragon spacecraft, the first (and currently only) private spacecraft to dock with the ISS.

The Falcon 9 is under contract with NASA to resupply the ISS, with ten more launches of the Dragon spacecraft scheduled for the coming years. The Falcon 9 will also be used to take other payloads - both governmental and commercial - into orbit.

The Falcon 9 is a two-stage-to-orbit vehicle that uses liquid oxygen and rocket-grade kerosene as fuel. Its upper stage is powered by SpaceX's own Merlin engine, which is derived from NASA's successful Apollo missions in the Sixties and Seventies.

Falcon 9 is still relatively young, but its importance can't be underestimated and, with every successful flight, SpaceX moves closer to its goal of bringing down the cost of reaching space.

The Falcon 9 launches from Cape Canaveral, Florida

SpaceX's Dragon spacecraft travel to the ISS on Falcon 9 rockets

"Falcon 9 is still young, but its importance can't be underestimated"

Manufacturer: SpaceX
Dates: 4 Jun 2010 - present
Total launches: 5
Successes: 5
Height: 54.3m (178ft)
Max payload: 10,454kg (23,050lb)
Total mass: 333,400kg (735,000lb)
Notable payloads: Dragon

Far-Sighted
Astronomy Centres

Stockists of
OSTARA Visionary Saxon
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What are asteroids made of?

The physical properties of huge space-rocks whirling around the Sun could hold clues to the origins of the Solar System

Protecting Earth is one of the main reasons why scientists keep a close eye on asteroids, which are space rocks of all shapes and sizes that can be found scattered throughout the Solar System.

It's unclear how meteoroids, the rocks that become meteors when they crash into Earth's atmosphere, were generated from asteroids. Still, NASA isn't ruling a link out and is examining asteroids to learn more about how the Solar System was formed.

Since planetary scientists believe planets gradually grew from rocks crashing into each other, the asteroid belt between Mars and Jupiter could be made up of the leftovers of the early Solar System.

Therefore, ferreting out the secrets of asteroids could also give scientists clues as to how the Solar System came to be. Possibly, it could even reveal how the Earth was born.

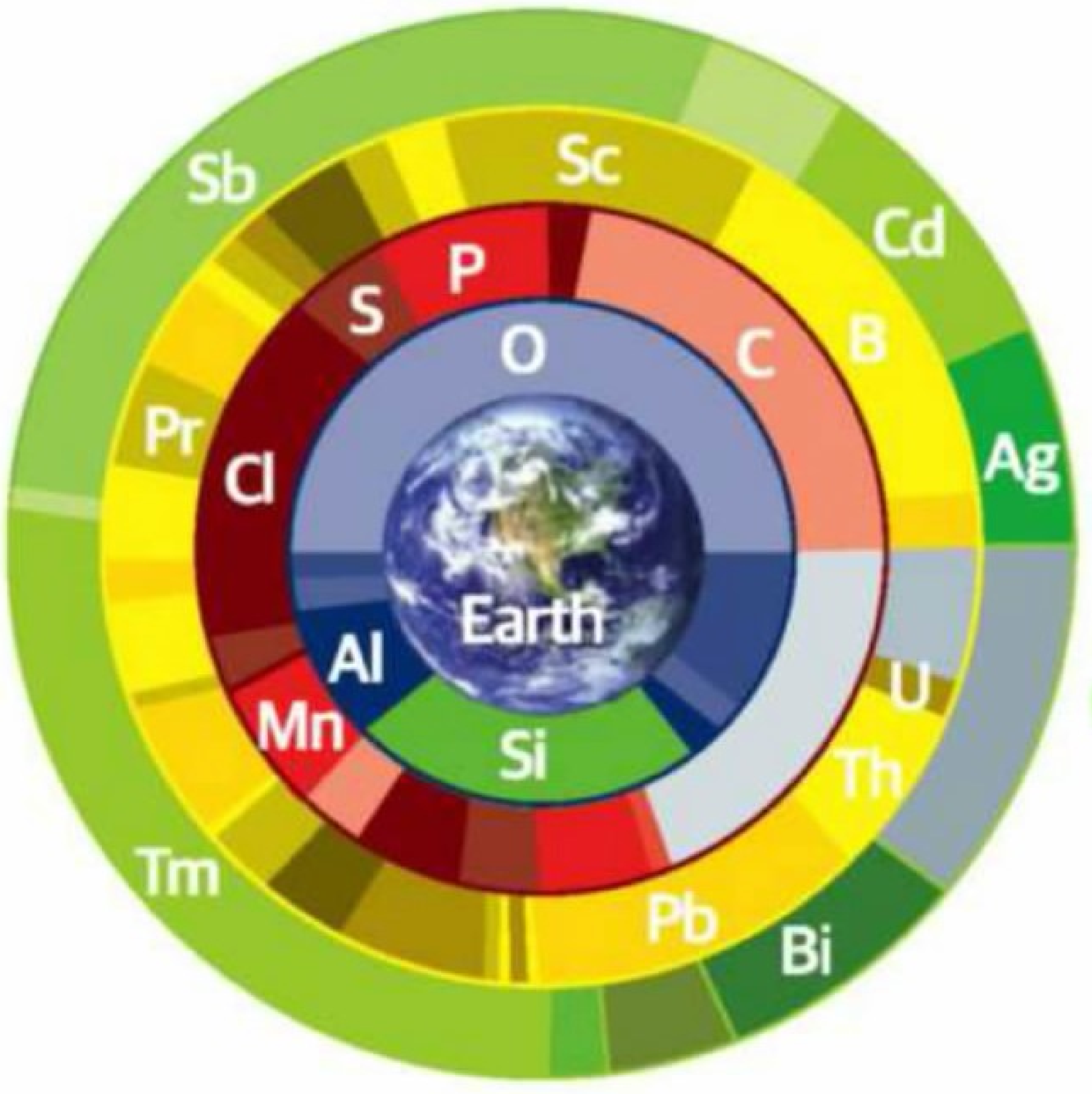
Studying asteroids is a challenge for scientists, however, because they are so small. A typical space rock is perhaps just a few metres across. However, the largest known asteroid in our Solar System, Ceres, is 950 kilometres (590 miles) in diameter and makes up a third of the mass of the known asteroid belt. However, through a telescope sitting on Earth, an asteroid of this size looks incredibly small. This makes asteroids difficult to see and study, but scientists are pretty crafty when it comes to getting information from a distance.

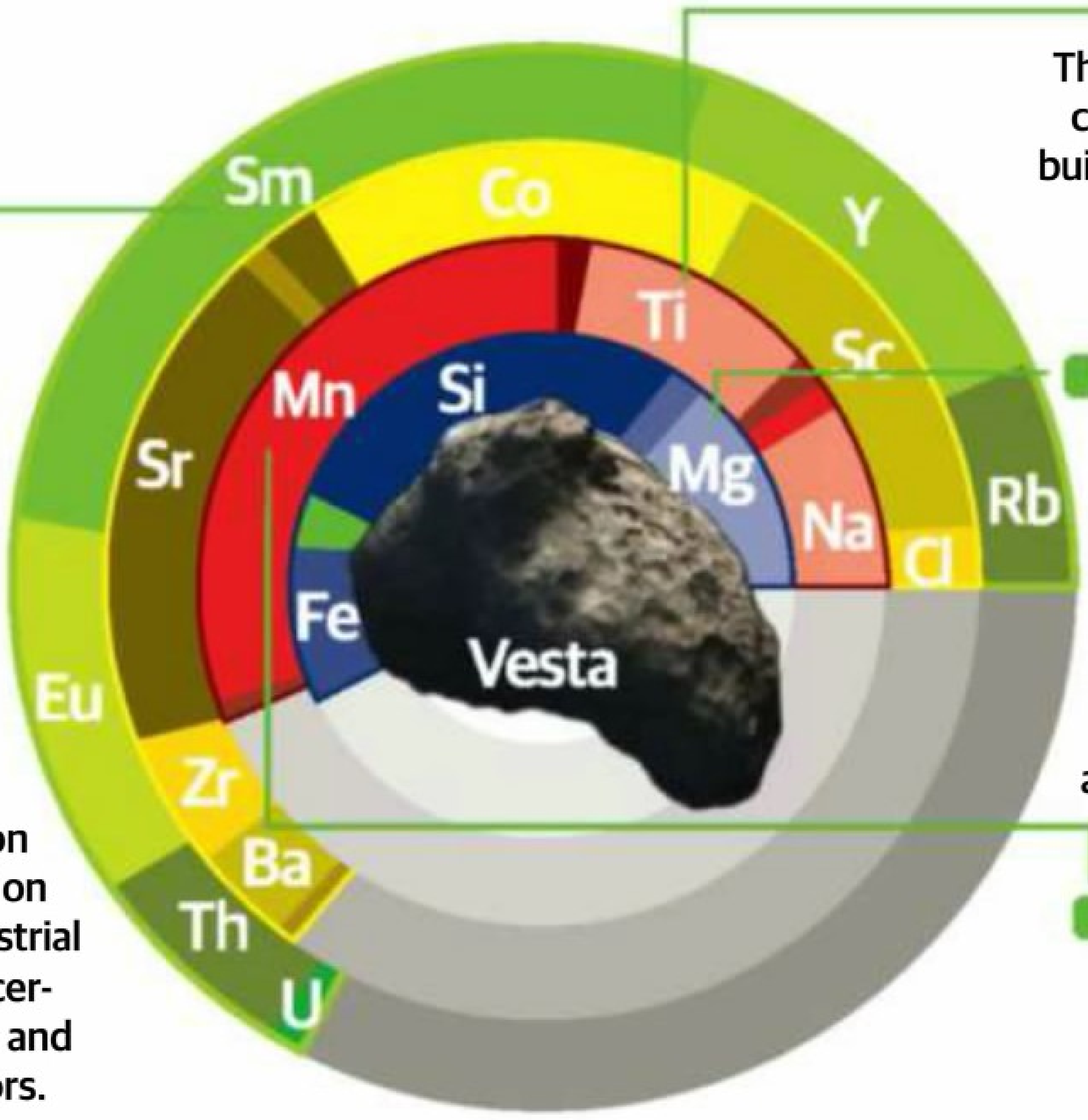
Most asteroids, according to NASA, can be classified in three groups: C-type (carbonaceous), S-type (siliceous) and X-type (various compositions). Around 75 per cent are C-type asteroids that lurk in the outer asteroid belt. They are very dark and probably lack helium, hydrogen and other lighter

> "In 1995, there were only 335 known near-Earth asteroids, however, today there are more than 9,700 catalogued"

Asteroid Ida and its moon, Dactyl. The spacecraft Galileo discovered the small moon when it passed by the asteroid in 1994

Explaining the elements





Titanium
This element could come in useful for building lightweight alloys for use in spacecraft.

Magnesium
A very common element in the universe, it is used in fertilisers and to make magnesium-aluminium alloys.

Samarium
This element, which is rare on Vesta, is used on Earth for industrial magnets, cancer-fighting drugs and nuclear reactors.

Manganese
An important element for stainless steel.

Ag - Silver
Al - Aluminium
B - Boron
Bi - Bismuth
C - Carbon
Cd - Cadmium
Cl - Chlorine
Mn - Manganese
O - Oxygen
P - Phosphorus
Pb - Lead
Pr-Praseodymium
S - Sulphur
Sb - Antimony
Sc - Scandium
Si - Silicon
Th - Thorium
Tm - Thulium
U - Uranium

Ba - Barium
Co - Cobalt
Cl - Chlorine
Eu - Europium
Fe - Iron
Mg - Magnesium
Mn - Manganese
Na - Sodium
Rb - Rubidium
Sc - Scandium
Si - Silicon
Sm - Samarium
Sr - Strontium
Th - Thorium
Ti - Titanium
U - Uranium
Y - Yttrium
Zr - Zirconium

Asteroids can range from just a few metres wide to almost 1,000km in diameter

'volatile' elements. S-type asteroids, about 17 per cent of the population, make up most of the inner belt rocks in the asteroid belt. They're a little more reflective and are usually made of metallic iron mixed with silicates of iron and magnesium. Squeezed in between these asteroids are X-types, which are mostly made up of metallic iron asteroids and the like. These are found in the middle of the asteroid belt.

While most asteroids sit safely between Mars and Jupiter, some approach Earth and sometimes cross its orbit. Scientists think most of these asteroids were 'disturbed' into different orbits due to Jupiter's gravity or collisions with other asteroids.

There are three types of near-Earth asteroids. Amors cross the orbit of Mars, but don't get very close to Earth. Apollos cross Earth's orbit in a period of one year or longer, while Atens also cross the orbit but in a shorter time frame – a year or less.

In the past two decades, space agencies and observatories around the world have discovered thousands of these types of asteroids. In 1995, there were only 335 known near-Earth asteroids, however, today there are more than 9,700 catalogued, according to NASA.

Since scientists believe we have now found more than 90 per cent of threatening asteroids that are more than one kilometre (0.6 miles) in diameter, NASA is now emphasising the search for finding near-Earth objects of 140 metres (460 feet) or greater.

Still, a much smaller object can cause a lot of damage. The dinosaurs were probably wiped out by a small body just ten kilometres (6.2 miles) in diameter that hit the Mexico area about 66 million years ago.

In Russia this year, more than 1,000 people were injured when a house-sized asteroid – 17 metres wide (56 feet) – detonated in the atmosphere. The event caught both the public and astronomers by surprise, demonstrating we still have a lot to learn about predicting meteor strikes on Earth.

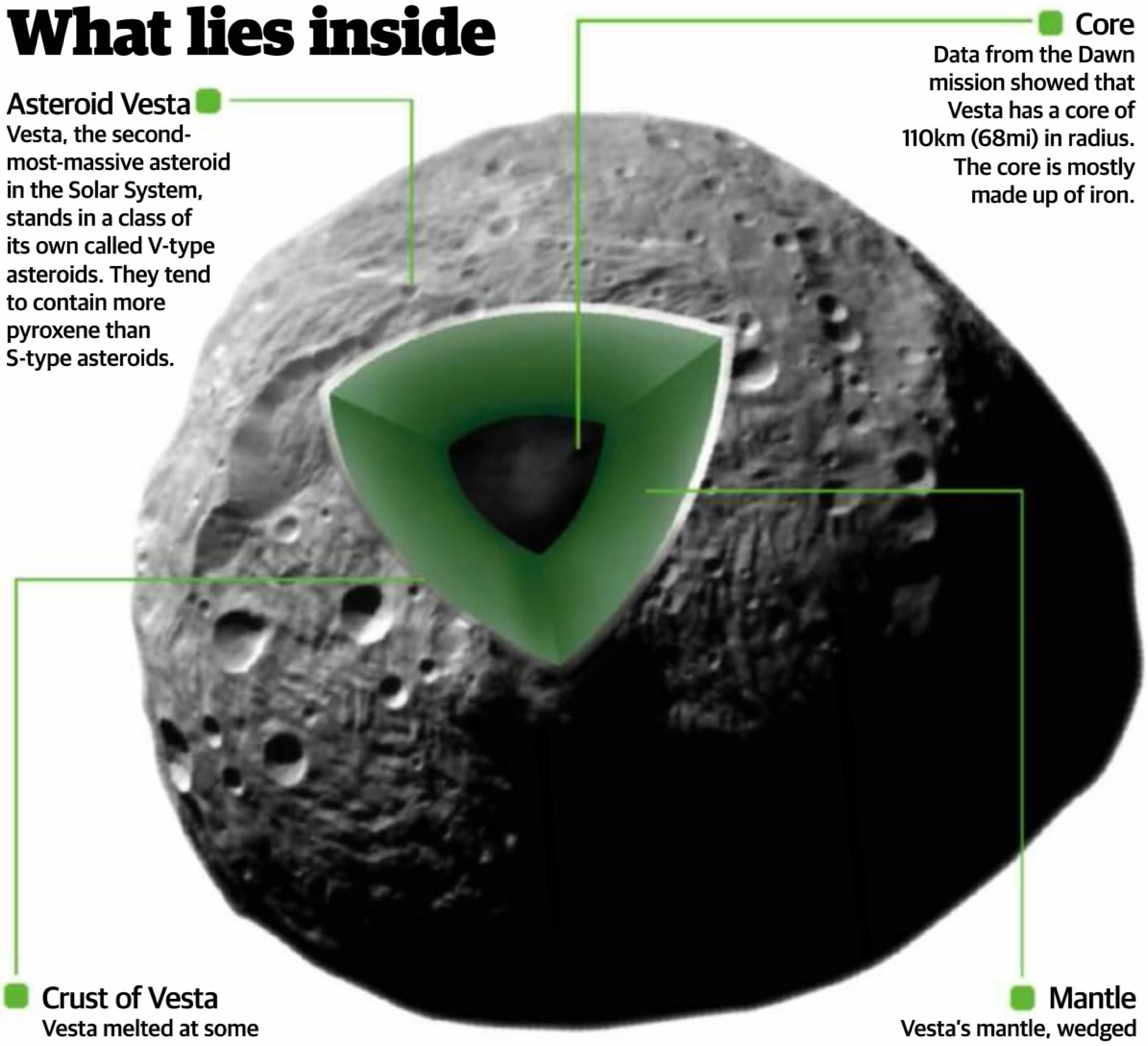
In more recent years, several space missions have ventured out to asteroids to get more information from closeup. NASA's Dawn mission, for example, scooted by the asteroid Vesta in 2011 and is now en route to Ceres.

Its closeup views revealed a battered world that, surprisingly, has some links to how the Moon was formed. Vesta and the Moon were each peppered by a population of space rocks ejected into the inner Solar System early in the Earth's history.

Both Jupiter and Saturn shifted their orbits in less than a million years. Their motions perturbed the asteroid belt and sent the rocks into planet-crashing orbits. This bombardment had been known about for decades – astronauts on the Apollo missions even discovered evidence of it on the Moon – but scientists didn't know until recently that Vesta had also experienced it.

The next step will be obtaining a sample of an asteroid and studying it here on Earth. Origins Spectral Interpretation Resource Identification Security Regolith Explorer (OSIRIS-REx) will journey into space in 2016, scoop up a bit of dirt from the Apollo asteroid (101955) 1999 RQ36, and return it to Earth by 2023 for further investigation.

What lies inside



Asteroid Vesta

Vesta, the second-most-massive asteroid in the Solar System, stands in a class of its own called V-type asteroids. They tend to contain more pyroxene than S-type asteroids.

Core

Data from the Dawn mission showed that Vesta has a core of 110km (68mi) in radius. The core is mostly made up of iron.

Crust of Vesta

Vesta melted at some point early in its history, producing a 'differentiated' core and a basaltic crust.

Mantle

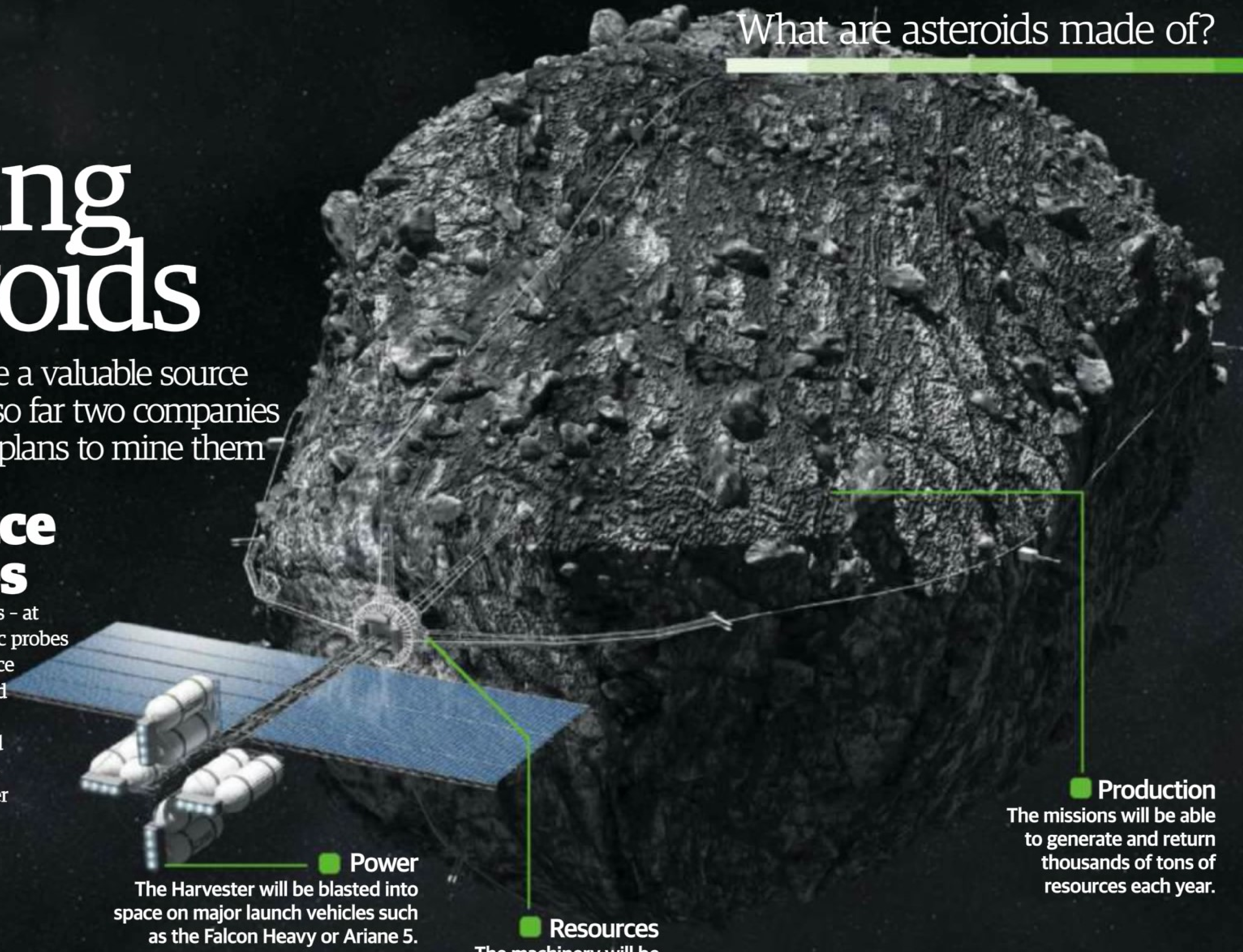
Vesta's mantle, wedged between the core and crust, likely includes olivine and diogenite.

Mining asteroids

Asteroids could be a valuable source of resources and so far two companies have announced plans to mine them

Deep Space Industries

Deep Space Industries plans – at some point – to send robotic probes on a one-way reconnaissance mission to potential asteroid mining sites. Later, larger DragonFly spacecraft would potentially pick up samples or small asteroids for further evaluation on Earth.



Power
The Harvester will be blasted into space on major launch vehicles such as the Falcon Heavy or Ariane 5.

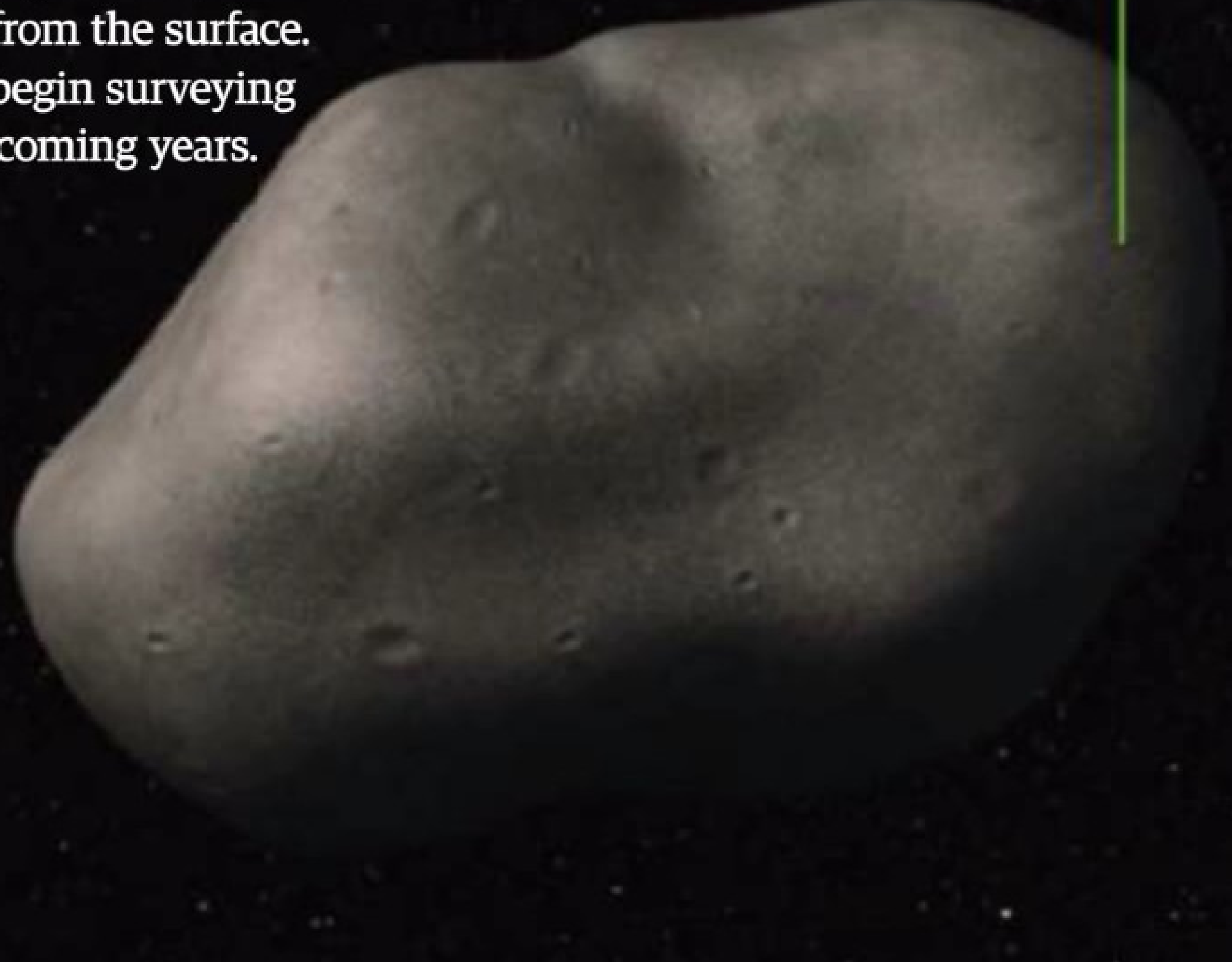
Resources
The machinery will be able to produce water, propellant and building materials for use on Earth or in space.

Production
The missions will be able to generate and return thousands of tons of resources each year.

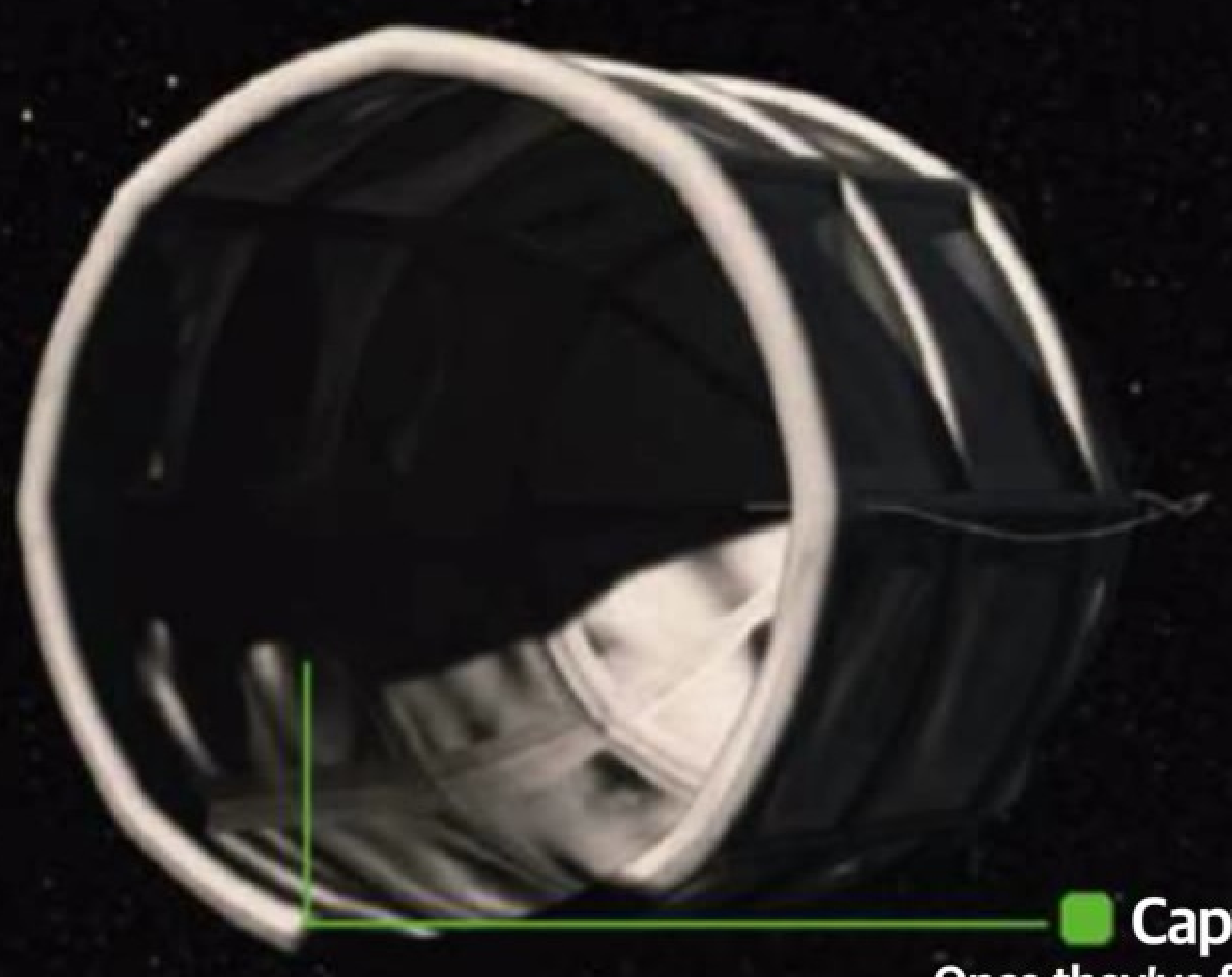
Deep Space Industries plans to use its Harvester to mine vital resources from asteroids

Planetary Resources

Planetary Resources first plans to scope out potential asteroids using a telescope. They will then capture a suitable asteroid and reposition it in a stable orbit near Earth, before sending a fleet of robotic spacecraft to return samples from the surface. They expect to begin surveying asteroids in the coming years.



Resources
Groups of robots will scour the asteroid to retrieve its resources.



Capture
Once they've found a suitable asteroid Planetary Resources will capture it to begin mining.

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When galaxies collide

These two interacting galaxies are providing us with a rare opportunity to observe a galactic collision

This stunning image, taken by the Hubble Space Telescope, shows the individual galaxies UGC 1810 (top) and UGC 1813 (bottom) in the process of colliding. Together, this pair of interacting galaxies is known as Arp 273. The interaction of galaxies is thought to be relatively common in the universe, particularly within galactic clusters, however, the opportunity to directly observe one such as this is incredibly rare.

The two galaxies are located around 300 million light years from Earth in the Andromeda constellation. A collision is actually thought to have already occurred, with UGC 1813 passing through the five times more massive UGC 1810. As a result, the smaller galaxy is now showing signs of intense star formation at its nucleus. It is possible, though, that they will collide again in the future due to their gravitational attraction.

Most galactic collisions result in the merging of the two galaxies' cores, but it's unknown if that will happen in this example. What can be seen is a 'bridge' of sorts between the two where their spirals have been pulled apart by the other. It is thought that the interaction of Arp 273 may bear similarities to the eventual fate of our own galaxy when we collide with Andromeda in around four and a half billion years.

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National Space Academy Education Officer

■ Sophie studied Astrophysics at university. She has a special interest in astrobiology and planetary science.

Megan Whewell

Education Team Presenter

■ Megan has a first-class Master's degree in Astrophysics and Science Communication and specialises in the topic of star formation.

Josh Barker

Education Team Presenter

■ Having achieved a Master's in Physics and Astrophysics, Josh continues to pursue his interests in space at the National Space Centre.

Gemma Lavender

Science journalist

■ Gemma holds a degree in Astrophysics and has worked as a science journalist for three years. She was recently elected as a fellow of the Royal Astronomical Society.

Jonathan O'Callaghan

Features editor

■ Jonathan read Physics and Astrophysics before becoming a writer on our sister publication **How It Works**, where he specialised in space science and exploration.

Europa is one of Jupiter's four major Galilean moons

SOLAR SYSTEM

Why do scientists think life could exist on Europa?

Malcolm Wyle

Europa is one of the most likely candidates for life in the Solar System chiefly because it is believed to contain a huge ocean situated beneath its icy crust.

In fact, Europa's global ocean contains slightly more than twice the volume of water that we have in the oceans here on Earth, and water is one of the key ingredients that scientists look out for when attempting to find life (as we know it) on other celestial bodies.

However, it is not only water that life needs in order to survive, but also oxygen. With Europa's oceans trapped beneath several miles of ice, it is cut off from the oxygen produced at the moon's surface by the interaction between energetic cosmic rays and the water ice.

However, space scientists now think that this constant rising, surfacing and coating of the crust by liquid water allows plenty of oxygen to pass into the oceans.

And if there is water, and oxygen, then life could exist on Europa, even if it will likely be in the form of simple organisms living around hypothetical thermal vents at the bottom of the moon's vast ocean. **SA**

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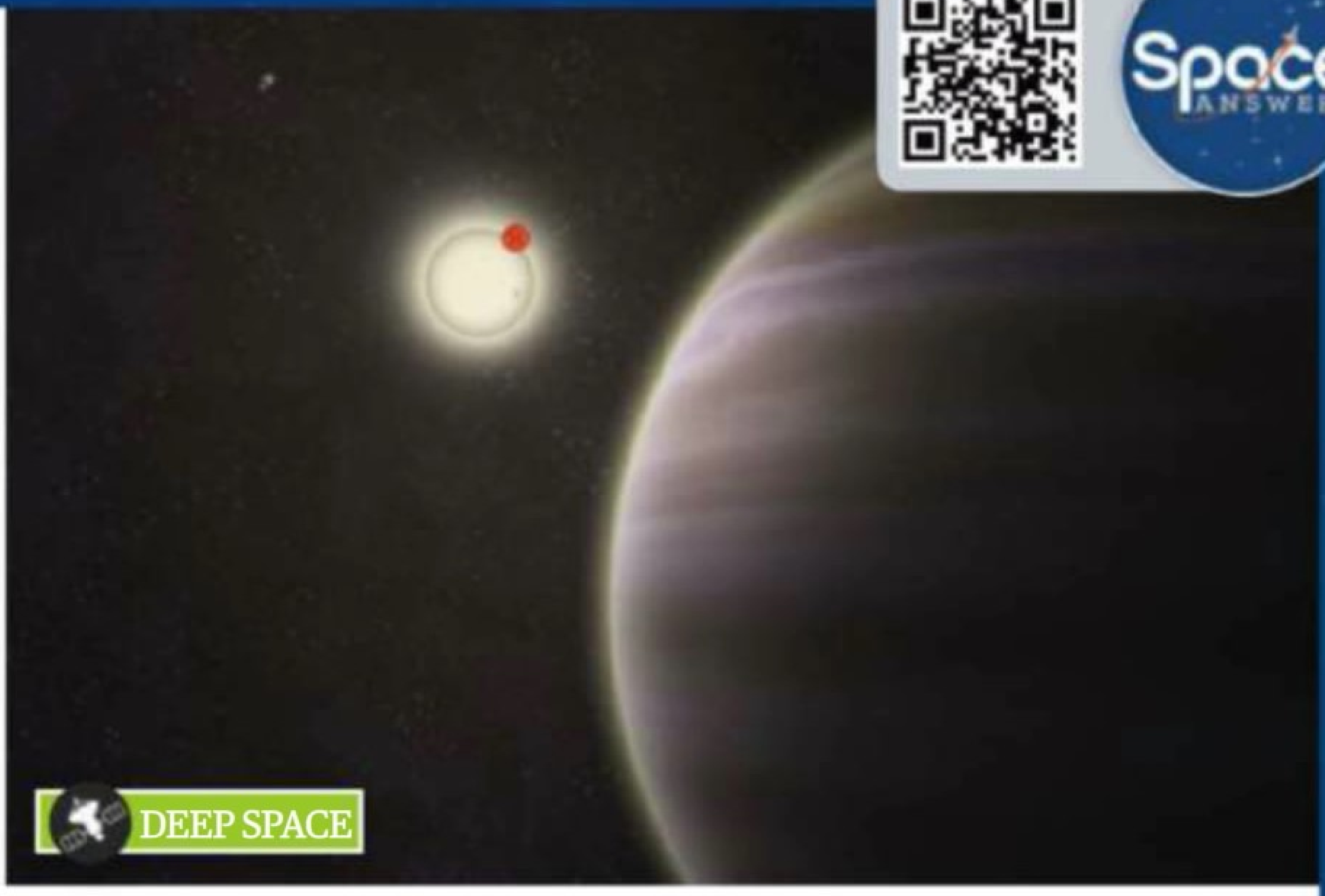
SPACE EXPLORATION

What do astronauts eat on the International Space Station?

Mike Dutton

There is a wide range of food available on the ISS, due to the various nationalities of astronauts on-board. American food usually comes in pouches and Russian food, like lamb with vegetables or chicken with rice, comes in cans. Both the cans and pouches then need to be heated before eating. There is also a range of dehydrated foods (which require water), such as Russian soups like borsch or a sweet Russian cottage cheese with nuts, called tvorog. ISS astronauts also have a choice of drinks with their dinner. They can add water to rehydrate coffee, tea, juice and milk. Even though the ISS is constantly experiencing microgravity, there is a table the astronauts congregate around to eat, although their food has to be held down to the table using bungee cords and Velcro to stop it floating around! **MW**

Crew members share a meal at a galley in the Unity node of the ISS



DEEP SPACE

If we could hear in space, what would stars sound like?

Gisele Sabourin

In general, the bigger the star, the lower the pitch. The sound they would make depends on their age and chemical composition. Our Sun, if it could be heard through space, vibrates with a song of many frequencies similar to the ringing of cathedral bells that are each hitting at different notes. If you've been near a cathedral you may notice that as the bells get louder, they chime at certain pitches when rung simultaneously. The Sun is similar in that it belts out rhythmic bass thumps over its background hum when certain frequencies overlap one another. If space were replaced with air and we could hear the Sun, it would be incredibly noisy – the output of the Sun is equivalent to 10 million keys of a piano. In fact you would struggle to hear anything else! **GL**

ASTRONOMY

Is there any way to protect Earth from meteors like the one that hit Russia?

Lizzie Marks

At the moment, we have nothing substantial to protect the Earth from meteoroids or asteroids. However, this does not mean that scientists are not working on something.

After the meteor that exploded over Chelyabinsk in Russia on 15 February 2013, injuring over 1,200 people, officials are looking to invest in a system to deflect or take out any approaching comets or asteroids, with nuclear strikes being one possible option. However, it seems that the Chelyabinsk meteor, on the grand scale of things, was quite small, at just 17m (56ft). Scientists are more interested in larger lumps of rock that could cause far more damage.

Less than two weeks after the Russian meteor, the Canadian Space Agency launched a microsatellite as part of Sentinel in the Sky, a programme which intends to provide an early warning system for space debris heading towards Earth.

NASA is currently funding a University of Hawaii team of astronomers to develop an Asteroid Terrestrial-Impact Last Alert System (ATLAS), which could give us about a week's warning in cases similar to that of Chelyabinsk.

At the moment, NASA's Spaceguard – a programme designed to identify threats – concentrates more on objects that are large enough to cause catastrophic destruction and unfortunately would not have uncovered the house-sized lump of rock that smashed through our atmosphere and broke up into fragments over Russia. **GL**

SOLAR SYSTEM

When is the best time to view Mars?

Keith Johnson

The best time to view planets from Earth changes as it depends not only on where the Earth is around the Sun, but also on where the planet is relative to Earth. For 2013, the first time we can view Mars from the northern hemisphere will be in summer. From about midway through July 2013, Mars will begin to rise in the east just before the Sun does in the mornings, and it won't be alone – Jupiter will be nearby and very bright, and in August it may also be possible to view Mercury low on the eastern horizon. This will all happen very early in the morning (about 4am), but will be well worth waking up for. Mercury will head back towards the Sun from August but Mars and Jupiter will be joined by the crescent Moon on the first day of September. Mars will continue to be visible later on in the mornings right through the winter and into 2014. **MW**

The LMC was once thought to be our closest galactic neighbour

DEEP SPACE

How far is it to the next nearest galaxy?

Geoff Gisbourne

The answer to just which galaxy is the closest to ours has been revised several times over the years. The Large Magellanic Cloud held the title up until 1994 before it was supplanted by the Sagittarius Dwarf Elliptical Galaxy. The LMC has recently been measured to be around 163,000 light years away whereas the Sagittarius Dwarf Elliptical Galaxy is currently some 70,000 light years away and on a polar orbit at 50,000 light years from our galaxy's core. Then the Canis Major Dwarf Galaxy was discovered in 2003. This is a small irregular structure that we can see from Earth in the constellation of Canis Major. This dwarf galaxy, which is only a short 42,000 light years away from our galaxy's centre, contains an estimated 1 billion stars, with a high percentage of these being red giants. This roughly elliptical midget is an even shorter 25,000 light years from our Solar System, but it wasn't always known about. **GL**

SPACE EXPLORATION

How does Chris Hadfield tweet from the ISS?

Sharon Fields

Astronauts on-board the ISS have their own personal internet connection. Prior to January 2010 any tweets from ISS astronauts had to be emailed to the ground where support staff would post them to Twitter on behalf of the astronauts, but a software update just over three years ago allows astronauts to bypass this extra stage and post directly to Twitter themselves. The on-board internet access is called the Crew Support LAN and allows the ISS crew to remotely access a computer on the ground and use its internet connection via an on-board laptop.

The very first live tweet from an astronaut on the ISS was by @Astro_TJ on Friday 22 January 2010, who said: "Hello Twitterverse! We r now LIVE tweeting from the International Space Station – the 1st live tweet from Space! :) More soon, send your ?s". **MW**

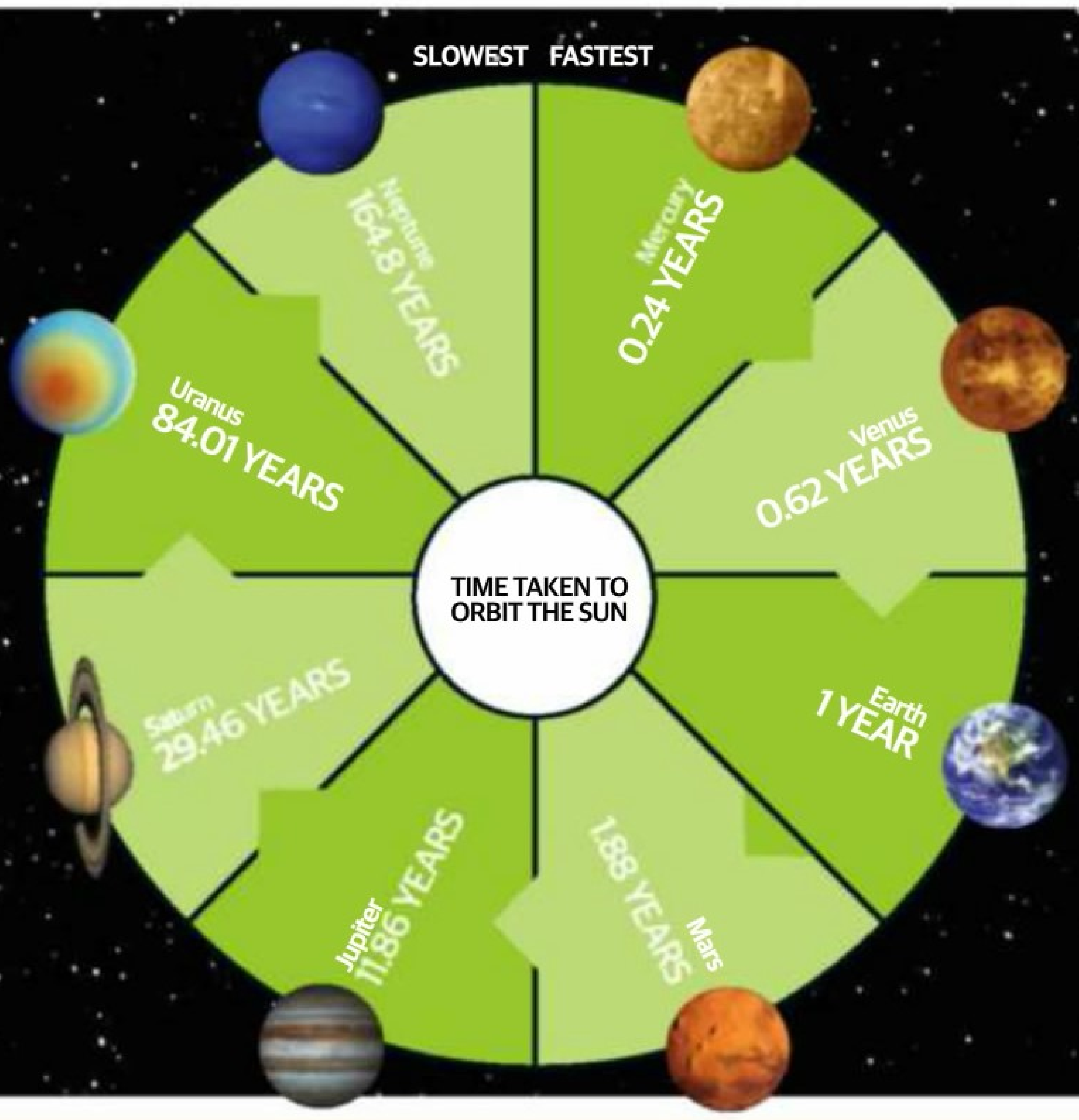
SOLAR SYSTEM

Which planet in the Solar System is moving the quickest?

Sarah MacKinnon

Mercury is the fastest planet in the Solar System. As a general rule when things move in circles, like planets orbiting around the Sun, the smaller the circle the faster they will move. This holds true for our Solar System as well, which is why Mercury is the fastest of the planets. The innermost planet takes just 88 days to get all the way around the Sun meaning it clocks in at an impressive 48km/sec (30 miles/sec). That's a round-the-world trip in less than 15 minutes!

Mercury's motion has always been of interest to astronomers, as not only was it very quick but for a long time its orbit couldn't be fully explained. When calculating Mercury's orbit using physics as described by Isaac Newton and Johannes Kepler we couldn't quite get it right and it wasn't until Albert Einstein gave us his theory of general relativity that things started to become clear. The Sun having a huge mass caused it to warp space around it, this warping has a small effect on the orbit of Mercury. Using Einstein's theory we could account for the difference between calculations and what we actually observed. **JB**



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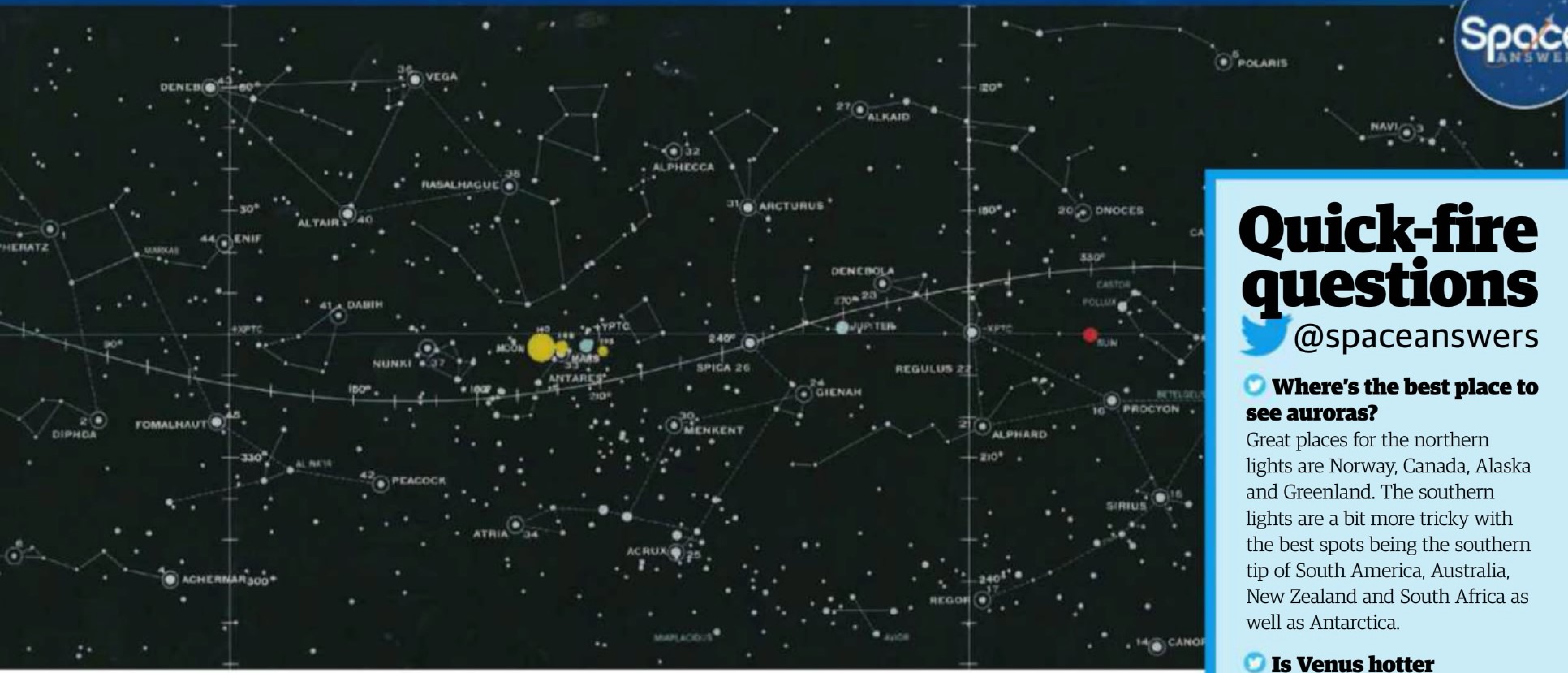


Quick-fire questions

@spaceanswers

Where's the best place to see auroras?

Great places for the northern lights are Norway, Canada, Alaska and Greenland. The southern lights are a bit more tricky with the best spots being the southern tip of South America, Australia, New Zealand and South Africa as well as Antarctica.

Is Venus hotter than Mercury?

While it's not the closest planet to the Sun, Venus is in fact hotter than Mercury. Unlike Mercury, Venus has a thick atmosphere that traps the Sun's heat bringing the temperature up to a sweltering 461°C (860°F)!

What's a shooting star?

Despite its name, it is not a star. It's another name for a meteoroid that burns up as it passes through the Earth's atmosphere.

How cold is the Moon?

Temperatures on the Moon can dip as low as -238°C (-400°F) in the lunar craters.

How wide is the Milky Way?

The Milky Way Galaxy is approximately 100,000 to 120,000 light years in diameter and 1,000 light years in thickness.

ASTRONOMY

Why are some stars denoted by numbers while others are given names?

Martin Bromberg

Since there are so many stars in the sky, not all of them can be given names. Many are assigned numerical values so that we can more easily keep track of them in catalogues.

An early attempt to catalogue stars came in 1603 when Johann Bayer began to name the brightest stars in each constellation using the Greek alphabet. The brightest star in the constellation was designated the alpha star, the second brightest was the beta star and so on. But his catalogue only named 1,564 naked eye stars, so many stars were left unidentified.

In 1712, John Flamsteed produced a star catalogue that numbered some of the undesignated stars. But he only managed to catalogue 2,554 stars, leaving many thousands of stars unnamed or unnumbered.

Subsequent star catalogues have sought to fill in the missing numbers, such as the Henry Draper catalogue that initially listed 225,300 stars to a low magnitude of ten and was later extended to 359,083 stars.

Variable stars, which are stars whose brightness is seen to fluctuate from Earth, are also numbered. In general, astronomers use a variation on the Bayer designation combined with the Latin name of the constellation in which the star lies. If a star does not have an existing Greek letter from the Bayer designation, then astronomers start with a letter. Examples are R Coronae Borealis and YZ Ceti. After using a combination of 334 letters, variable stars start to take on numbers such as V335, V336 and so on. **JB**

SPACE EXPLORATION

How does NASA protect Curiosity from solar flares?

Jenny Cullen

To ride out the intensity of a solar flare, NASA puts Curiosity to sleep until solar storms pass. Since the Red Planet does not have a substantial atmosphere or a magnetic field, it gets the brunt of the Sun's temper. In fact, a large cloud of hot plasma was recently thrown out from the Sun, bathing Mars in highly charged particles.

The rover is built to withstand the harsh conditions on Mars but given that Curiosity recently suffered a glitch in its memory, NASA decided to put the rover on standby by turning its instruments and sensors off for the 22 hours it took for the storm to pass. These high-energy storms are also known to impact electronics, causing erroneous commands.

Curiosity also had to withstand being blasted by a solar flare on its way to Mars last year. However, with a protective coating that managed to survive long-term exposure on the International Space Station, the rover is able to protect itself pretty well from the harsh environments of space. **GL**

Quick-fire questions

@spaceanswers

How much does a spacesuit cost?

They can cost anywhere up to $12 million (£7.8 million).

Which star is the biggest?

Red hypergiant V1489 Cygni, at around 1,650 times the Sun's radius, is the largest star that we currently know of.

Which planet has the strongest gravity?

Since it holds the greatest amount of mass, Jupiter has the strongest gravitational pull.

What year was NASA founded in?

NASA was founded in 1958, replacing the National Advisory Committee for Aeronautics (NACA), after President Eisenhower signed the National Aeronautics and Space Act.

How long is a day on Mars?

A day on Mars is not much longer than a typical Earth day. A sidereal day on Mars lasts 24 hours, 37 minutes and 22 seconds.

SPACE EXPLORATION

What went wrong during the recent Dragon launch?

Steve Williams

SpaceX's latest Dragon spacecraft launched on 1 March 2013. Ten minutes into the flight, the solar panels – which power the capsule – were set to unfurl. However, this did not happen and since the battery on-board could only provide power for 14 hours, SpaceX had to think fast.

On top of this, the Dragon capsule was also having problems with its thrusters. Tanks containing oxidiser to ignite the fuel were not pressurising properly and, as a result, only one of the four thruster pods was operating. Without at least two pods, the solar panels could not be deployed.

From the ground, engineers realised that the hardware used to unfold the panels was getting colder and colder. Sending an override command to the Dragon, SpaceX managed to get not just a second thruster tank to pressurise, but also kickstarted the panels into working nearly two hours after launch. Five hours after launch, SpaceX CEO Elon Musk announced that the Dragon capsule's final two thrusters were online and operational.

It's still not clear why this happened, however, it is thought that the oxidising chemical may have frozen and, getting stuck along the pipes that carry it, may have blocked the flow causing the thrusters to fail. Other possibilities are that other debris may have got caught in the pipe or a valve somehow became stuck. **GL**

SPACE EXPLORATION

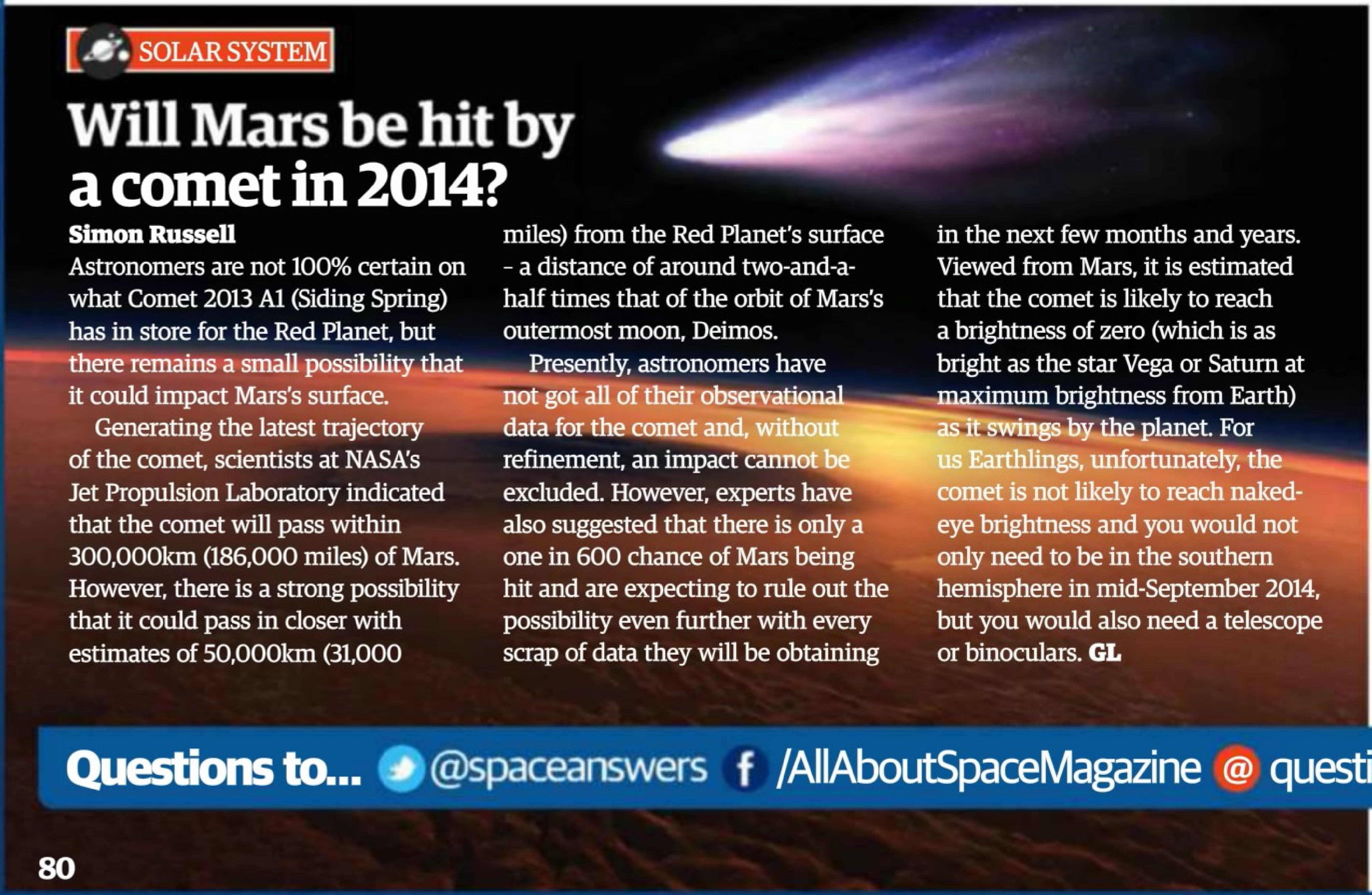
How fast is the Atlas V rocket?

James Harris

In January 2006, an Atlas V rocket, which at the time was launching the New Horizons mission on its journey to Pluto, set a new record for highest launch velocity when leaving the Earth's atmosphere at a speed of about 58,000 km/h (36,000mph). If you were travelling at this speed, it would only take you around 41 minutes to travel around the Earth's equator, which is 40,075km (24,902 miles). Picking up speed, the rocket reached a top speed of around 76,000km/h (47,000mph). A non-stop flight from Denver to New York that would normally take you almost four hours, would take two minutes and 16 seconds at this speed! **GL**

SOLAR SYSTEM

Will Mars be hit by a comet in 2014?



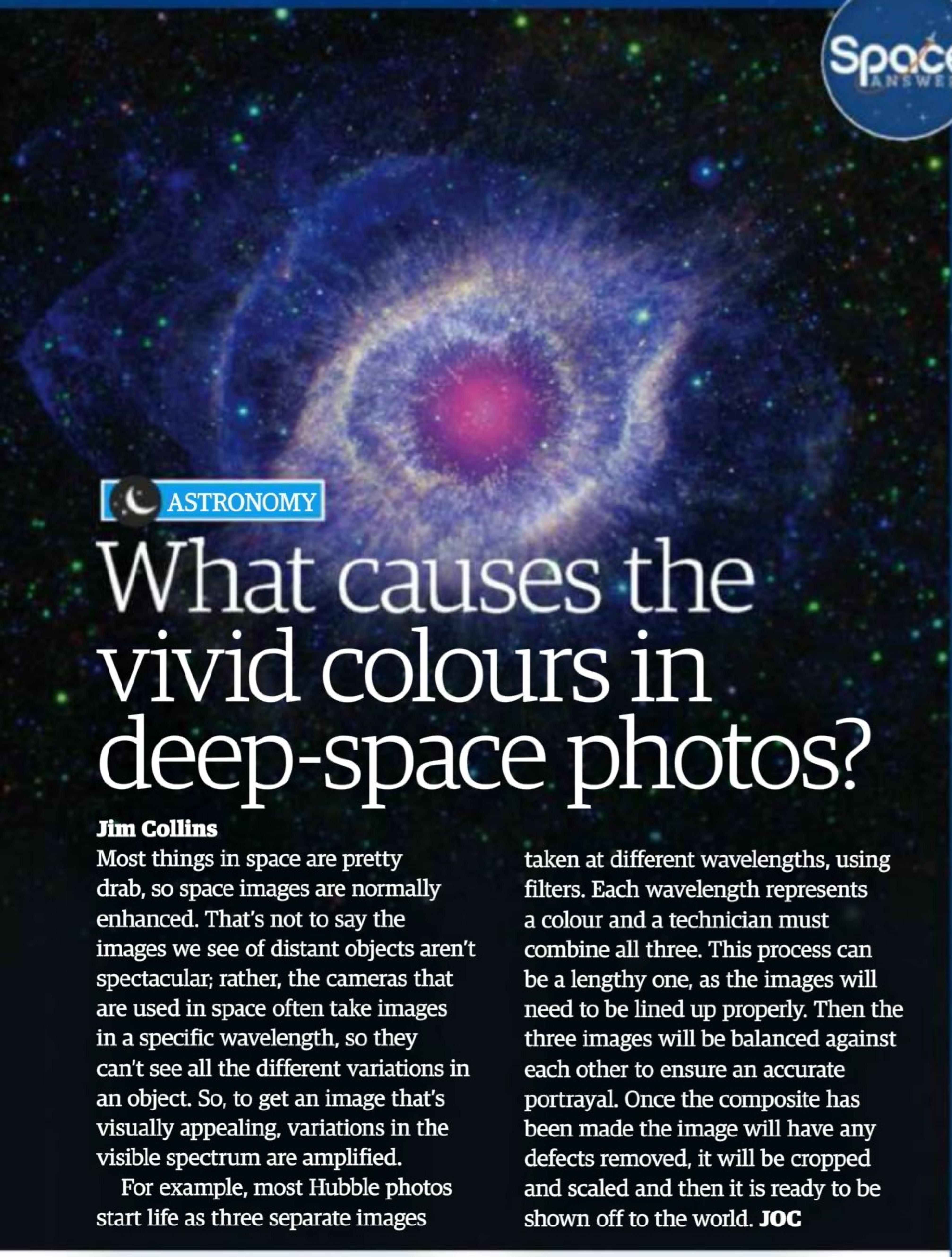
Simon Russell

Astronomers are not 100% certain on what Comet 2013 A1 (Siding Spring) has in store for the Red Planet, but there remains a small possibility that it could impact Mars's surface.

Generating the latest trajectory of the comet, scientists at NASA's Jet Propulsion Laboratory indicated that the comet will pass within 300,000km (186,000 miles) of Mars. However, there is a strong possibility that it could pass in closer with estimates of 50,000km (31,000 miles) from the Red Planet's surface – a distance of around two-and-a-half times that of the orbit of Mars's outermost moon, Deimos.

Presently, astronomers have not got all of their observational data for the comet and, without refinement, an impact cannot be excluded. However, experts have also suggested that there is only a one in 600 chance of Mars being hit and are expecting to rule out the possibility even further with every scrap of data they will be obtaining in the next few months and years. Viewed from Mars, it is estimated that the comet is likely to reach a brightness of zero (which is as bright as the star Vega or Saturn at maximum brightness from Earth) as it swings by the planet. For us Earthlings, unfortunately, the comet is not likely to reach naked-eye brightness and you would not only need to be in the southern hemisphere in mid-September 2014, but you would also need a telescope or binoculars. **GL**

Questions to... @spaceanswers /AllAboutSpaceMagazine questions@spaceanswers.com



ASTRONOMY

What causes the vivid colours in deep-space photos?

Jim Collins

Most things in space are pretty drab, so space images are normally enhanced. That's not to say the images we see of distant objects aren't spectacular; rather, the cameras that are used in space often take images in a specific wavelength, so they can't see all the different variations in an object. So, to get an image that's visually appealing, variations in the visible spectrum are amplified.

For example, most Hubble photos start life as three separate images taken at different wavelengths, using filters. Each wavelength represents a colour and a technician must combine all three. This process can be a lengthy one, as the images will need to be lined up properly. Then the three images will be balanced against each other to ensure an accurate portrayal. Once the composite has been made the image will have any defects removed, it will be cropped and scaled and then it is ready to be shown off to the world. **JOC**

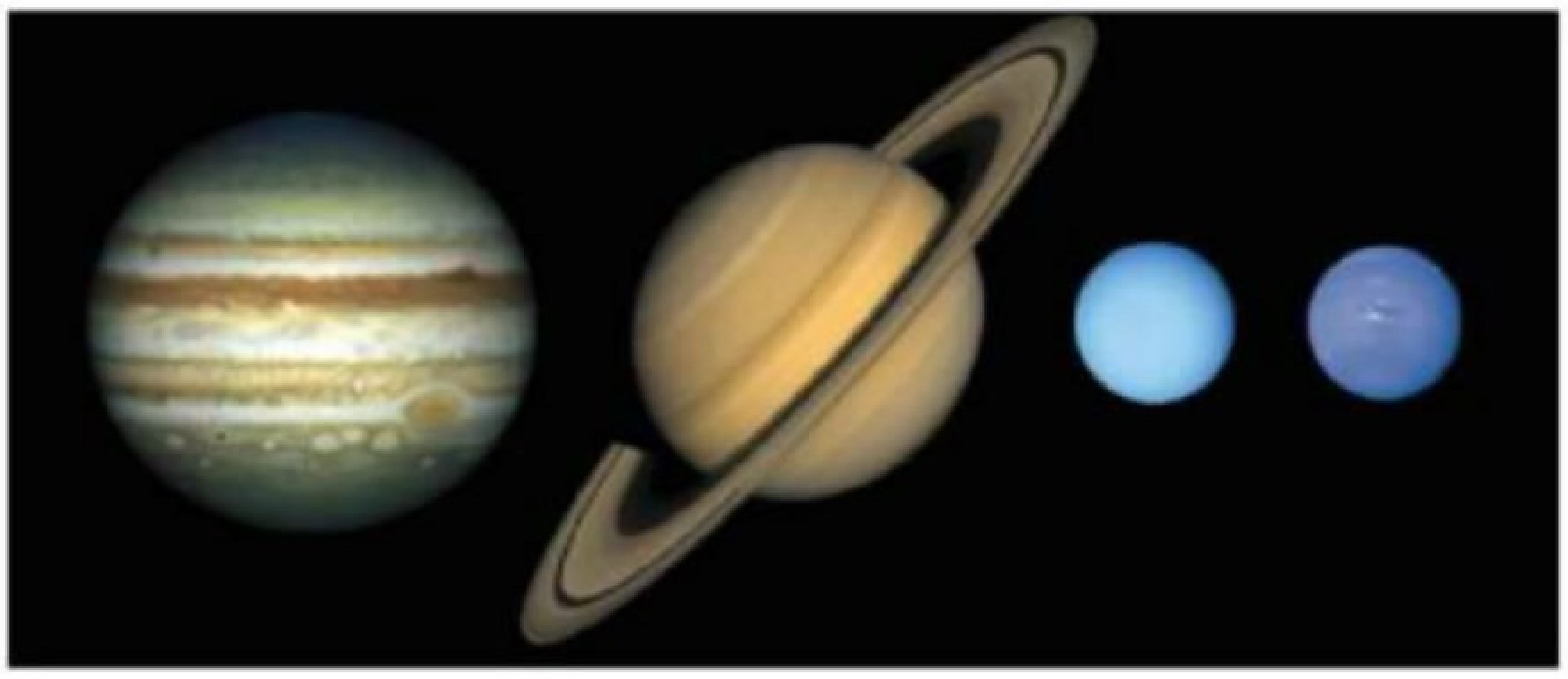
SOLAR SYSTEM

What are the cores of the gas giants made up of?

Will Pitenger

Gas giant cores are often referred to as being rocky by astronomers. However, this is a little misleading, especially in the case of Jupiter, as its core is made of liquid compounds, including molten heavy metals such as hydrogen surrounded by ice. Also, the closer you move to Jupiter's centre, the higher the pressure and temperature gets. What this essentially means is that its core is most likely to be quite slushy with a consistency of both a solid and a liquid.

The core-accretion model, which attempts to explain the formation of gas giants, suggests there is almost definitely a core. Here, a ten Earth-mass protoplanet formed, which quickly swept up gas from the primordial disc that formed our Solar System to develop a massive atmosphere around it and become Jupiter. The theory is that the rocky core would have had to have formed very early in the history of the Solar System in order to capture such a high percentage of gases. **GL**



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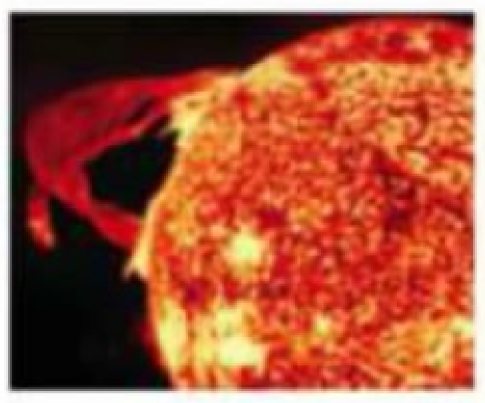
Next Issue

THE POWER OF QUASARS

The gigantic force at the heart of every galaxy

How do they form?
How are they studied?
Where can they be found?

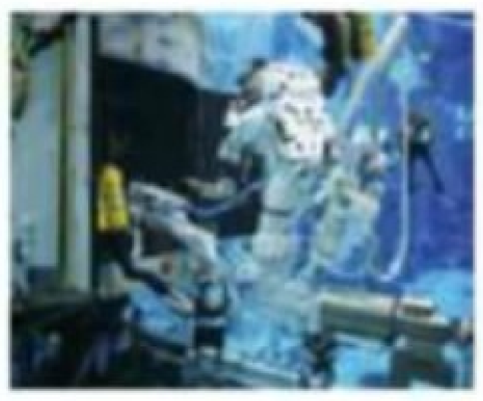


DEADLY SOLAR FLARES

How massive storms on the surface of the Sun affect life on Earth

ALL ABOUT TITAN

A marvellous alien world with methane lakes and seas



NASA DIVE MISSIONS

The underwater facilities that train astronauts for space

ASTEROID EXPLORATION
GRAVITY SLINGSHOTS
SPACECRAFT RE-ENTRY
REFLECTOR TELESCOPES
VIEWING THE MOON
INSIDE MISSION CONTROL

In orbit
30 May 2013

STARGAZER

GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

In this issue...

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93 **Astronomy kit reviews** A look at this month's astronomy must-haves

Seeing double stars

It's a little known fact that around 50% of all the stars in the night sky are double or multiple stars...

Double stars can either be stars which look very close to each other due to a line of sight effect for us here on Earth, or they can actually be bound to each other through gravitation – in other words, they orbit around their common centre of gravity. These are arguably the most interesting as their position relative to each other can change over time.

There are a couple of 'naked eye' double stars we can see from Earth, but for most you will need a telescope. The rule of thumb here is that bigger is better, so the larger your telescope, the more double stars you are likely to be able to resolve as two distinct stars, otherwise known as 'splitting'. Some doubles are so close that, even with the largest telescopes on Earth, you can never discern them as individual stars. Sometimes the stars can look like a single egg-shaped star as they are apparently very close to each other. Others are relatively easy to split and often can be of differing brightness or colours. For close doubles, you'll need to use a fairly high magnification if you can, around 100x or so.

> "The larger the telescope, the more double stars you are likely to be able to resolve"

5 amazing double stars

1 Mizar and Alcor

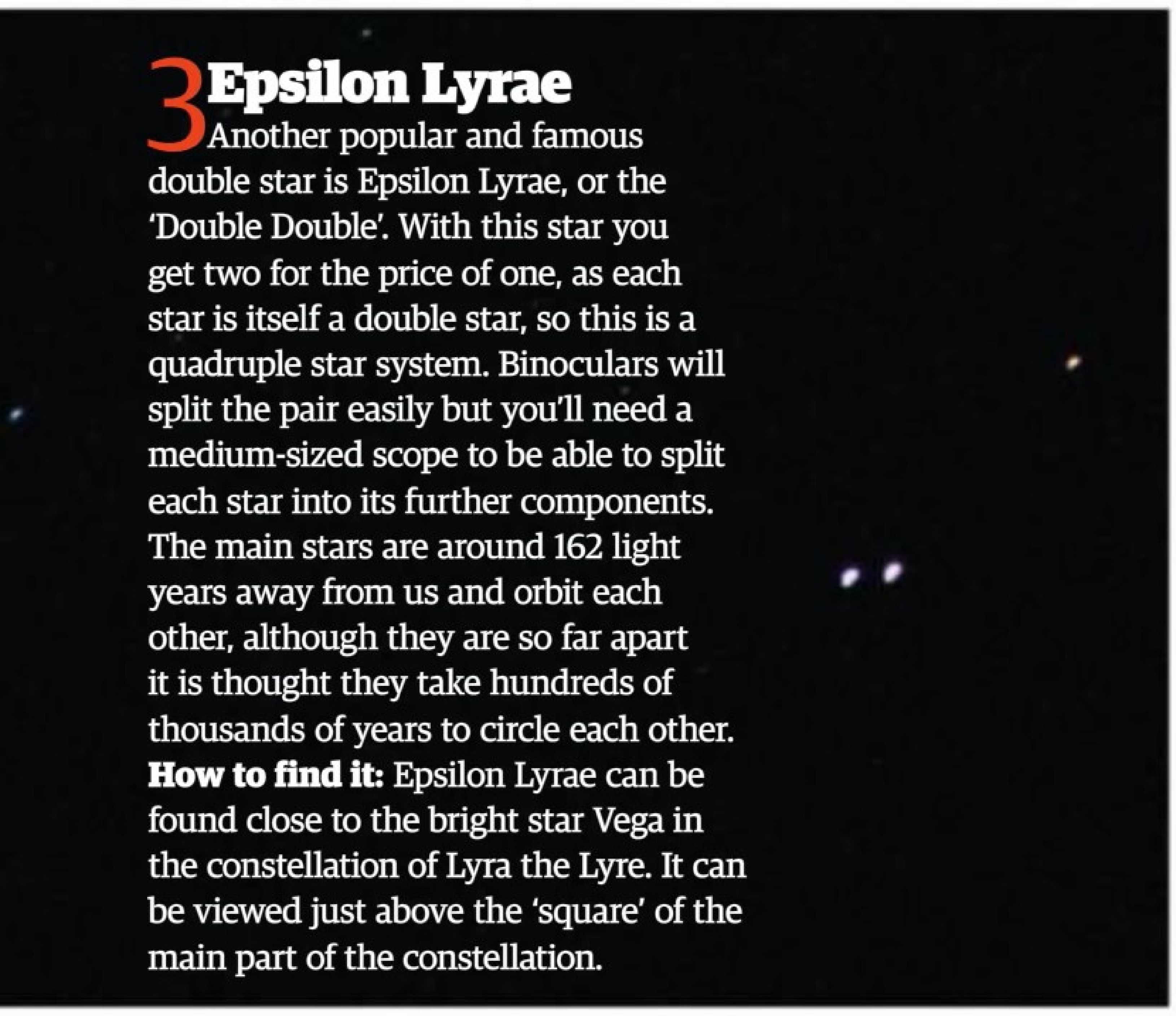
The two stars which make up this pair have separate names, which is unusual for double stars. They are also a good test of eyesight as you should be able to make out these two stars without any optical aid. Sometimes also called the 'Horse and Rider' this double star is interesting for several reasons: not only is it a visual binary, it's also a multiple star system which consists of six stars. The system lies 83 light years from Earth, while Mizar and Alcor are 1.1 light years apart from each other.

How to find it: Mizar and Alcor make up the 'star' in the middle of the handle of the famous 'Plough' or Big Dipper asterism. Look very closely and you will be able to see that it's actually two stars.

2 Winnecke 4

In 1764, Charles Messier was hunting for a nebula in the constellation of Ursa Major but never found it. Instead, he came across this double star and catalogued it. Also known as Messier 40, this object has caused much confusion, some thinking that Messier made a mistake in listing a double star. Recent observations suggest this is an optical double rather than a true binary star. These stars are too faint to be seen with the naked eye and require a telescope to make them out.

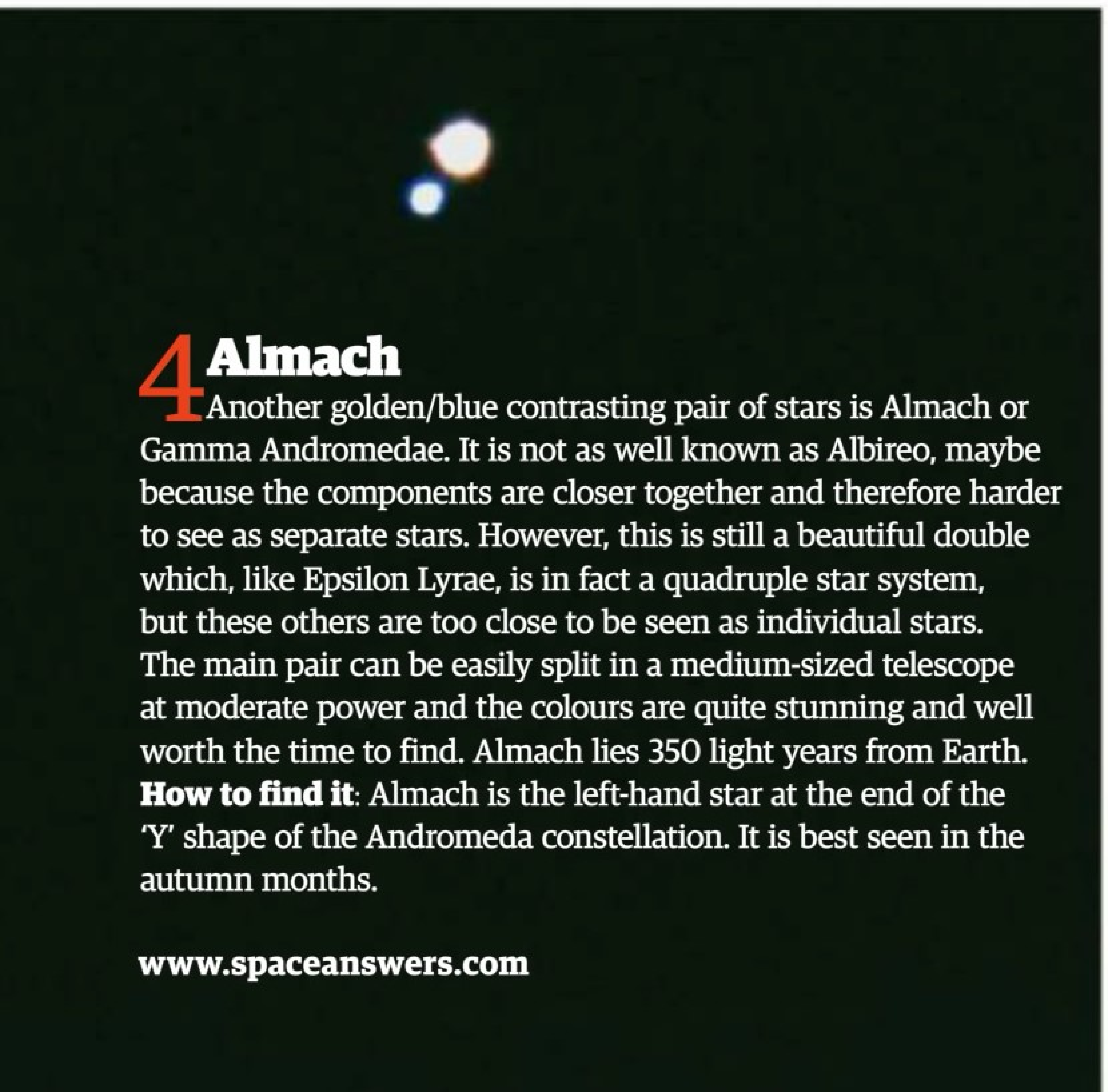
How to find it: Winnecke 4 lies just above the star Megrez which connects the handle of the 'Dipper' to the 'Bowl'. It is 510 light years from Earth.



3 Epsilon Lyrae

Another popular and famous double star is Epsilon Lyrae, or the 'Double Double'. With this star you get two for the price of one, as each star is itself a double star, so this is a quadruple star system. Binoculars will split the pair easily but you'll need a medium-sized scope to be able to split each star into its further components. The main stars are around 162 light years away from us and orbit each other, although they are so far apart it is thought they take hundreds of thousands of years to circle each other.

How to find it: Epsilon Lyrae can be found close to the bright star Vega in the constellation of Lyra the Lyre. It can be viewed just above the 'square' of the main part of the constellation.



4 Almach

Another golden/blue contrasting pair of stars is Almach or Gamma Andromedae. It is not as well known as Albireo, maybe because the components are closer together and therefore harder to see as separate stars. However, this is still a beautiful double which, like Epsilon Lyrae, is in fact a quadruple star system, but these others are too close to be seen as individual stars. The main pair can be easily split in a medium-sized telescope at moderate power and the colours are quite stunning and well worth the time to find. Almach lies 350 light years from Earth.

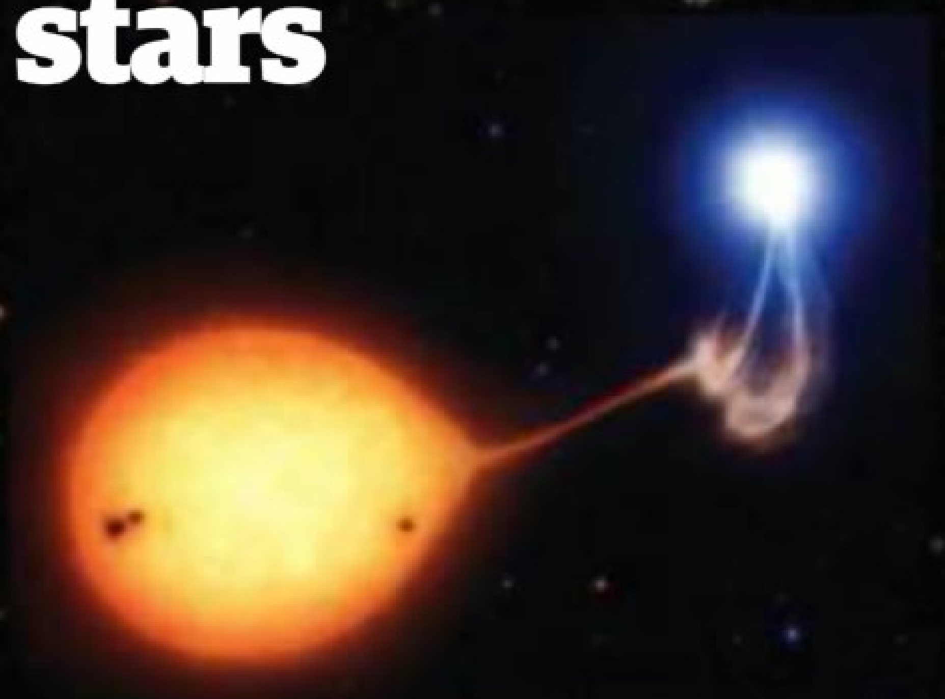
How to find it: Almach is the left-hand star at the end of the 'Y' shape of the Andromeda constellation. It is best seen in the autumn months.

5 Albireo

This lovely double star is an easy target for even a small telescope or binoculars. The brightest of the pair is a golden yellow colour which contrasts with the fainter bluish coloured secondary and is a striking colour contrast. This is probably one of the most popular double stars to view in the entire night sky as it is so easy to find and such a well-contrasted pair. The stars are 35 arcseconds apart and it is not yet known if they are orbiting around each other. Albireo lies around 430 light years from us.

How to find it: Albireo is the star marking the head of Cygnus in the constellation of the Swan and is best seen in the summer when it rides high in the night sky.

Interacting stars



There are binary stars, two stars that orbit around their common centre of gravity, that can interact with each other physically. These are often in a very close orbit and, in the case of AM Herculis pictured above, this consists of a red dwarf star which is having matter pulled away from it by a white dwarf star. This matter forms what is known as an 'accretion disc' around the white dwarf. This will then fall on to the surface of the white dwarf at irregular intervals.

Through this interaction the stars will vary in brightness as the matter from the 'ordinary' star crashes on to the white dwarf causing it to flare up often at irregular intervals due to nuclear fusion reactions converting hydrogen to helium at a very fast rate. This type of binary star is known as a cataclysmic variable, a term which describes the nature of the object rather well. It is known that these stars have intense and complex magnetic fields surrounding them. Stars such as these often form the basis of 'novas', stars which will suddenly increase in brightness many hundredfold. If the stars are massive enough then such interactions can trigger a supernova explosion.

What's in the sky?

The constellations of late spring bring us a range of wonders to enjoy on balmy evenings...

Globular Cluster M5

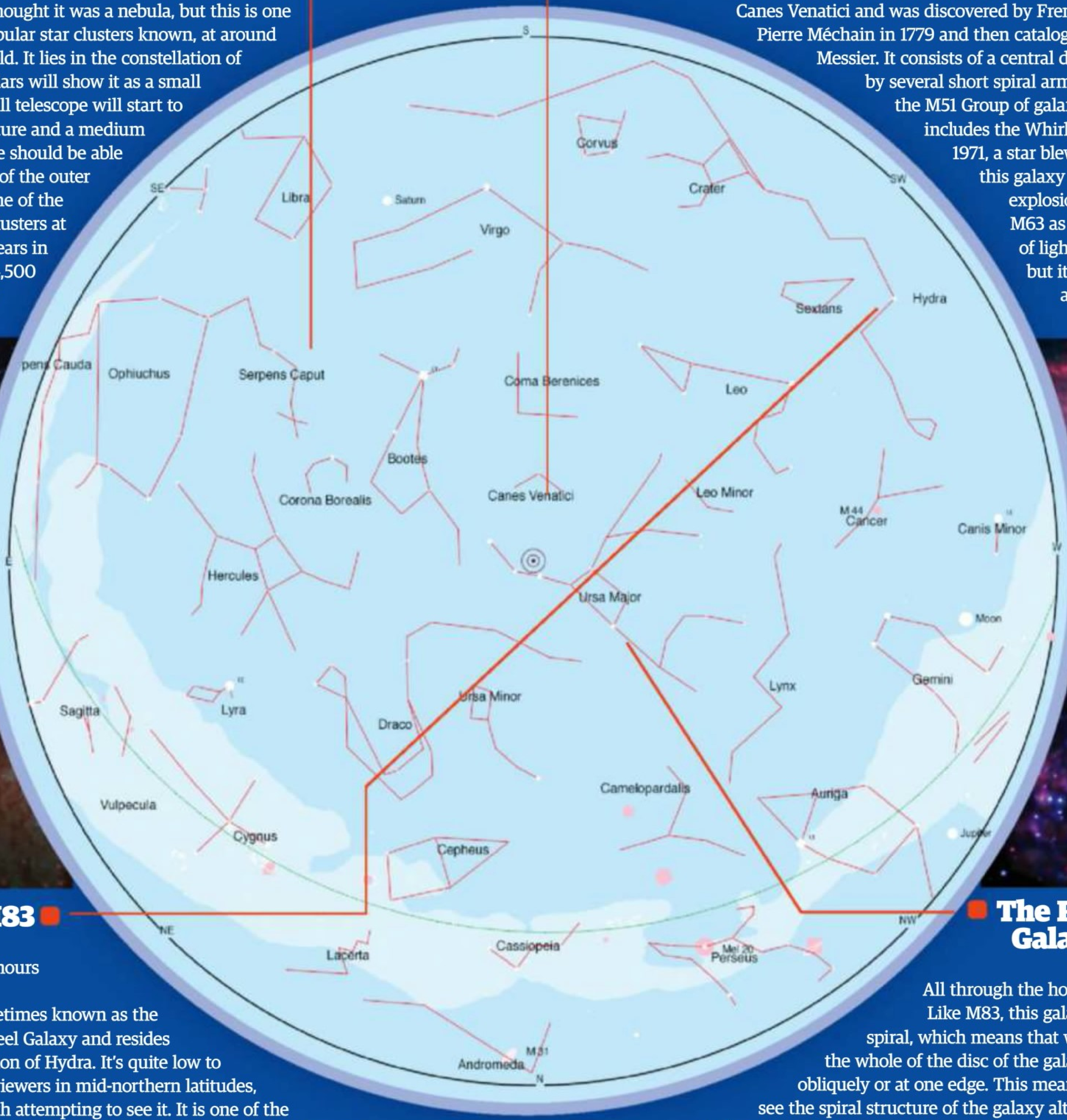
Viewable time: All through the hours of darkness

If you live far away from artificial lights, you might be able spot Messier 5 with your unaided eye. Charles Messier in fact thought it was a nebula, but this is one of the oldest globular star clusters known, at around 13 billion years old. It lies in the constellation of Serpens. Binoculars will show it as a small fuzzy star; a small telescope will start to show its true nature and a medium to large telescope should be able to resolve many of the outer stars. It is also one of the larger globular clusters at some 165 light years in diameter. It is 24,500 light years away from Earth.

Sunflower Galaxy M63

Viewable time: All through the hours of darkness

One of the prettiest spiral galaxies in the night sky is arguably M63, or the Sunflower Galaxy. It sits in the constellation of Canes Venatici and was discovered by French astronomer Pierre Méchain in 1779 and then catalogued by Charles Messier. It consists of a central disc surrounded by several short spiral arms. It belongs to the M51 Group of galaxies which also includes the Whirlpool Galaxy. In 1971, a star blew itself apart in this galaxy as a supernova explosion. You can see M63 as a faint smudge of light in binoculars, but it looks better in a medium-sized telescope.



Northern hemisphere

Galaxy M83

Viewable time: All through the hours of darkness

M83 is also sometimes known as the Southern Pinwheel Galaxy and resides in the constellation of Hydra. It's quite low to the horizon for viewers in mid-northern latitudes, but it's well worth attempting to see it. It is one of the brightest spiral galaxies and shows up in binoculars. It is around 15 million light years distant from Earth. This galaxy has a central 'bar' of stars similar, it is thought, to the Milky Way. It is also a face-on spiral galaxy, so we can see its structure quite easily. There have been six known supernovas discovered in this galaxy.

The Pinwheel Galaxy M101

Viewable time: All through the hours of darkness

Like M83, this galaxy is a face-on spiral, which means that we're looking at the whole of the disc of the galaxy rather than obliquely or at one edge. This means it is easier to see the spiral structure of the galaxy although you will need a telescope with a large aperture. The Pinwheel lies some 21 million light years away from us in the constellation of Ursa Major. It is 70 per cent larger than the Milky Way at 170,000 light years in diameter. It has a disc mass of around 100 billion solar masses and a small central bulge of 3 billion solar masses.

Globular Cluster M4

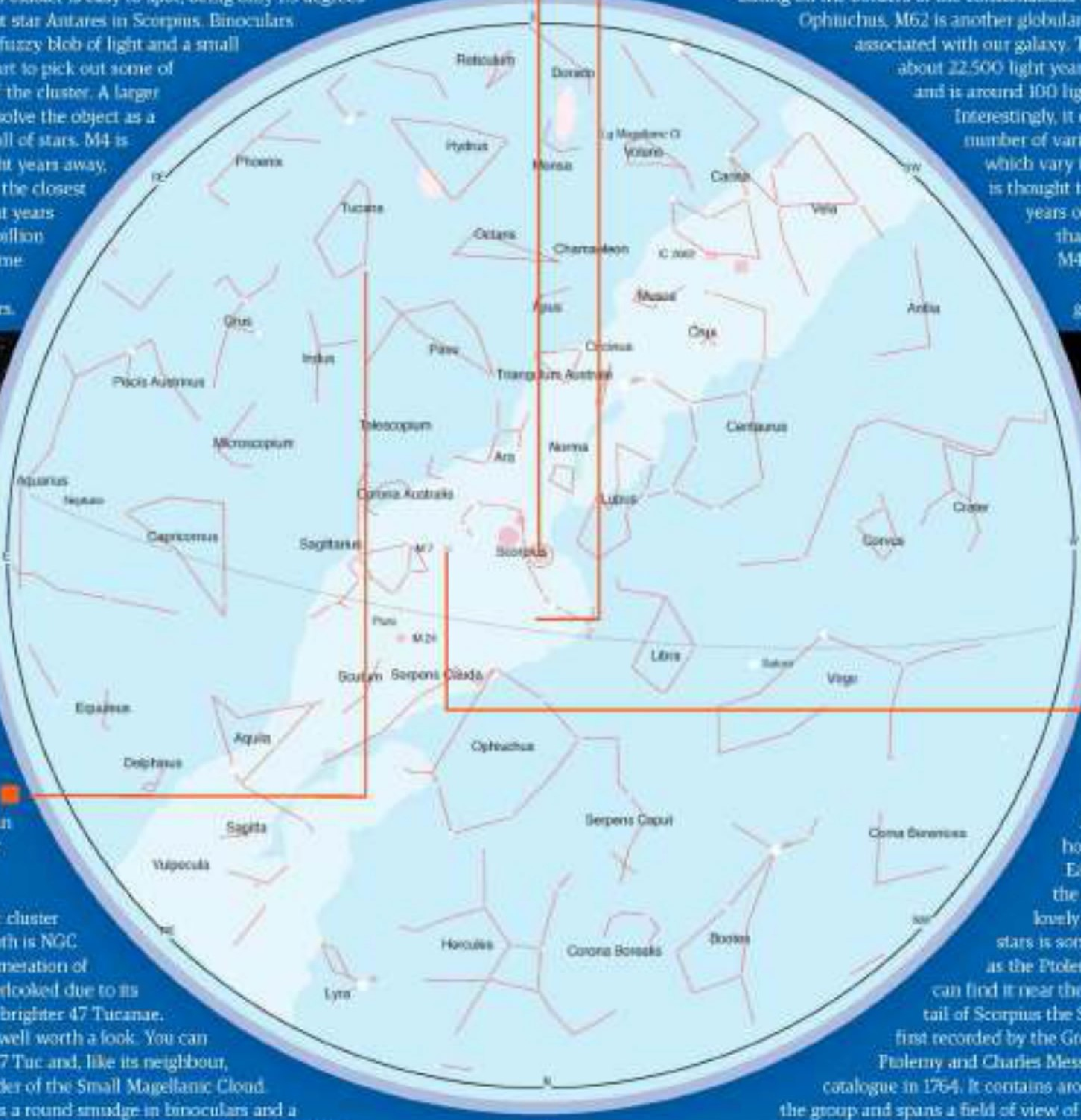
Viewable time: All through the hours of darkness

This globular star cluster is easy to spot, being only 1.3 degrees west of the bright star Antares in Scorpius. Binoculars will show it as a fuzzy blob of light and a small telescope will start to pick out some of the outer stars of the cluster. A larger telescope will resolve the object as a tight, granular ball of stars. M4 is around 7,200 light years away, making it one of the closest to us. It is 75 light years across. It is 12.2 billion years old and home to many tens of thousands of stars.

Globular Cluster M62

Viewable time: All through the hours of darkness

Sitting on the borders of the constellations of Scorpius and Ophiuchus, M62 is another globular cluster of stars associated with our galaxy. This one resides about 22,500 light years away from us and is around 100 light years across. Interestingly, it contains a large number of variable stars; stars which vary in brightness. It is thought to be 11.8 billion years old. It is dimmer than its neighbour M4, because it lies at considerably greater distance.



Globular Cluster NGC 362

Viewable time: An hour or two after sunset until the early hours

Another globular cluster to view this month is NGC 362. This conglomeration of stars is often overlooked due to its proximity to the brighter 47 Tucanae. However, this is well worth a look. You can find it south of 47 Tuc and, like its neighbour, it sits on the border of the Small Magellanic Cloud. It will show up as a round smudge in binoculars and a telescope will start to resolve many of the stars in the cluster. It is younger than many of the other globular clusters around our galaxy, being a mere 10.3 billion years of age.

Open Cluster M7

Viewable time: All through the hours of darkness

Easy to spot with the naked eye, this lovely open cluster of stars is sometimes known as the Ptolemy Cluster. You can find it near the 'stinger' in the tail of Scorpius the Scorpion. It was first recorded by the Greek astronomer Ptolemy and Charles Messier put it in his catalogue in 1764. It contains around 80 stars in the group and spans a field of view of 1.3 degrees. M7 is around 980 light years distant, which equates to an actual diameter of 25 light years. It is thought to be about 200 million years old.

Southern hemisphere

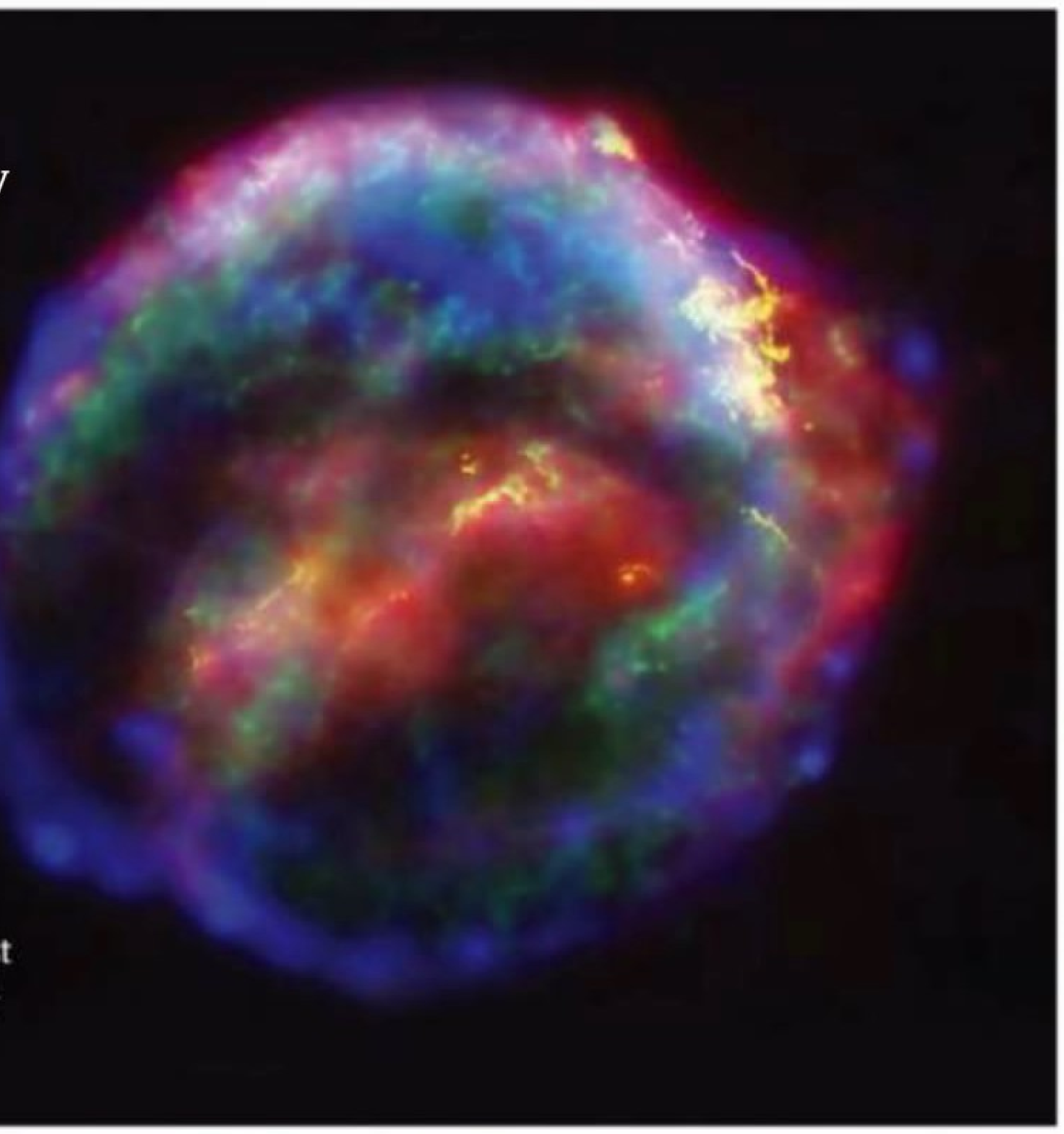
See a supernova

At the end of their life, some massive stars explode with such ferocity that they outshine the rest of their galaxy's stars combined...

Stars are exploding all the time, but most of these events happen in distant galaxies where we need large telescopes to detect them. Just occasionally, though, a massive star will end its life in a cataclysmic explosion, known as a supernova, in our own Milky Way Galaxy and when it does it can lead to the sudden appearance of a star so bright it can be seen in broad daylight. This can last for several weeks until the remains of the star fade away.

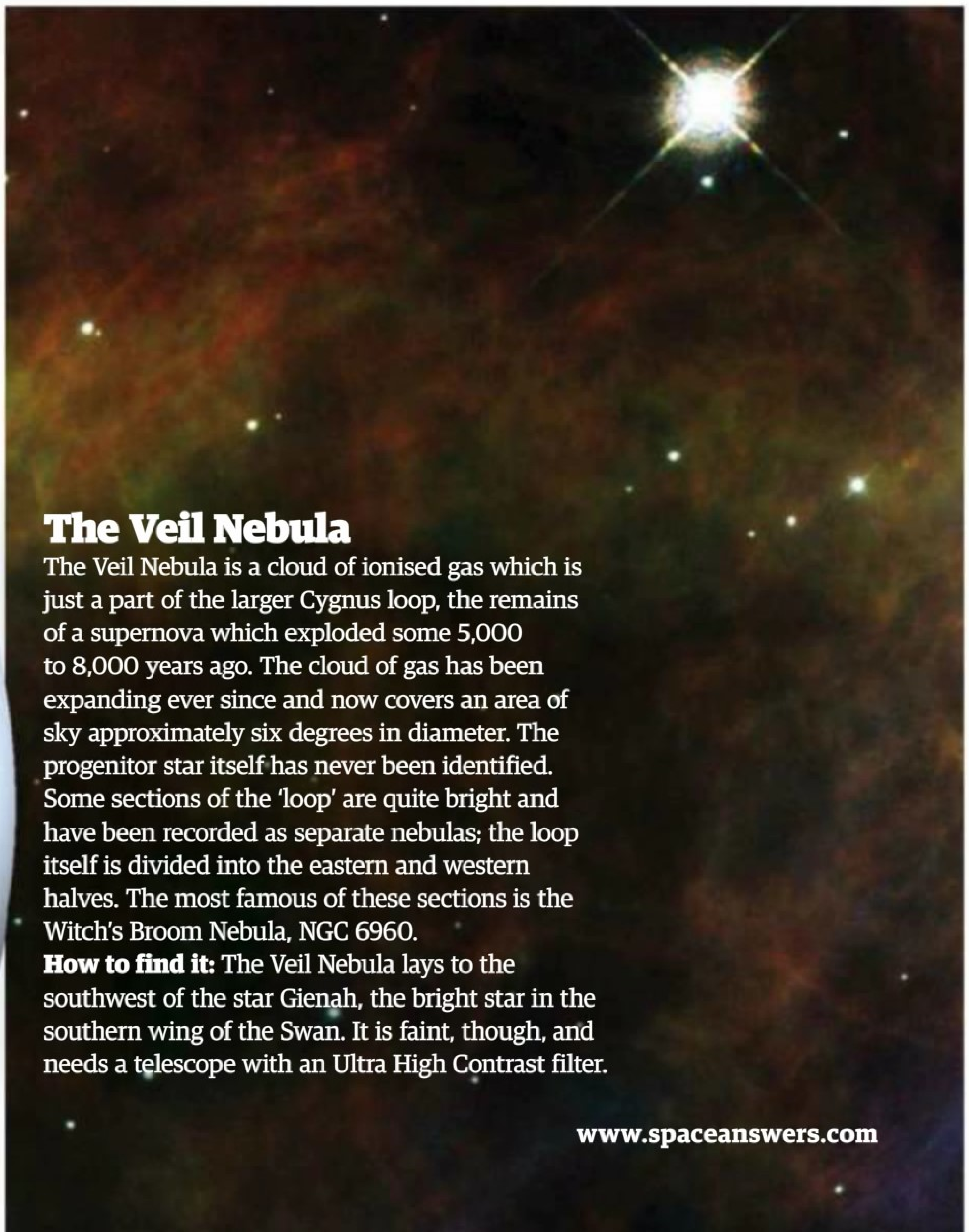
This is a very rare event, though, and may happen only once in several centuries. Although there are none visible at the moment, we can never tell for sure which stars are going to explode and when but there are candidates, these stars are coming to the end of their lives and could 'blow' at any time. One such star is the red supergiant we know as Betelguese, the bright star which marks the shoulder of Orion the Hunter. There are plenty of other potential supernova candidates, however, and astronomers, both professional and amateur, monitor these regularly. Fortunately, none of the stars near to the Earth are big enough to become supernovas, so we are quite safe. ●

Kepler's supernova



On 17 October 1604, the famous German astronomer Johannes Kepler at his observatory in Prague recorded a supernova in the constellation of Ophiuchus so bright that it was seen in daylight for more than three weeks. It is the most recent known naked-eye supernova so far. The star was around 20,000 light years away in our own galaxy and when it exploded it outshone every other star and planet in the night sky except for Venus. The supernova remnant is still a focus of a lot of study by astronomers and astrophysicists.

How to find it: Kepler's supernova remnant lays near the easternmost foot of Ophiuchus the Serpent Bearer, about halfway between Sagittarius and Scorpius. It is best seen in the summer months for mid-northern latitude observers.



The Veil Nebula

The Veil Nebula is a cloud of ionised gas which is just a part of the larger Cygnus loop, the remains of a supernova which exploded some 5,000 to 8,000 years ago. The cloud of gas has been expanding ever since and now covers an area of sky approximately six degrees in diameter. The progenitor star itself has never been identified. Some sections of the 'loop' are quite bright and have been recorded as separate nebulas; the loop itself is divided into the eastern and western halves. The most famous of these sections is the Witch's Broom Nebula, NGC 6960.

How to find it: The Veil Nebula lays to the southwest of the star Gienah, the bright star in the southern wing of the Swan. It is faint, though, and needs a telescope with an Ultra High Contrast filter.

Tycho's supernova

The supernova of 1572 recorded by Tycho Brahe was one of the most important celestial events in history as it helped to usher in a new way of thinking about the cosmos. Despite being discovered by many individuals, it was named after Brahe because he wrote an important book about it. It was seen in the constellation of Cassiopeia and like Kepler's supernova, which followed a couple of decades later, it was visible in daylight. It is now so faint it can only be seen with professional telescopes and cameras. It lays some 8,000 to 9,000 light years away from Earth.

How to find it: Although this supernova remnant is beyond the reach of amateur telescopes, it lies to the north of the right-hand 'v' of the 'w' shape of the Cassiopeia constellation.

Vela supernova

The Vela supernova remnant is the remains of a star which blew itself to pieces somewhere between 11,000 and 12,300 years ago. As this is a constellation of the southern hemisphere it cannot be seen from northern latitudes. This supernova was one of the closest known to us at a distance of approximately 825 light years. The star which exploded formed the Vela Pulsar, which was proof for astronomers that such supernovas form neutron stars. The cloud of gas left over glows very brightly with X-rays, a remnant of the energy with which the supernova exploded.

How to find it: The Vela supernova remnant lays to the southeast of the bright star Suhail in the Vela constellation. It is very faint and requires photography to show it up well.

The Crab Nebula

In 1054, a star in the constellation of Taurus blew itself apart and was seen and recorded by Chinese astronomers. It was bright enough to show in daylight for many days. As the star faded the remnants of it expanded into space and this growing cloud of gas was noted by Charles Messier in his catalogue in 1758. Because of its shape it became known as the Crab Nebula. The star itself collapsed and became a very dense spinning neutron star. This was subsequently discovered to be pulsating at 30 times a second; one of the first pulsars to be found.

How to find it: You will need a telescope to see it now as a faint misty smudge of light just north of the star Zeta Taurii, the tip of the left hand horn of the Bull.

The next supernova

It really is difficult to predict when and where the next supernova will explode in our galaxy. We just have to keep a careful watch. There are some candidates, however, which we know are large stars that are reaching the end of their lives. One of the most well known of these candidates is Betelguese in the Orion constellation. This is the bright orange star which marks the Hunter's right shoulder on the left of the constellation as we see it.

How do we know it is coming to the end of its life? Well, its size for one thing tells us this. It is a red supergiant star and lays about 630 light years from us, so when it does finally blow it will be one of the most spectacular sights to ever be seen in the heavens. When is this likely to happen? Again, we just don't know. It might not happen for another million years, or it could happen next week. When it does eventually blow it will be easily seen in daylight, probably for several weeks. It will then fade away and will radically alter the look of the constellation. All we can do is watch and wait.

Me & My Telescope

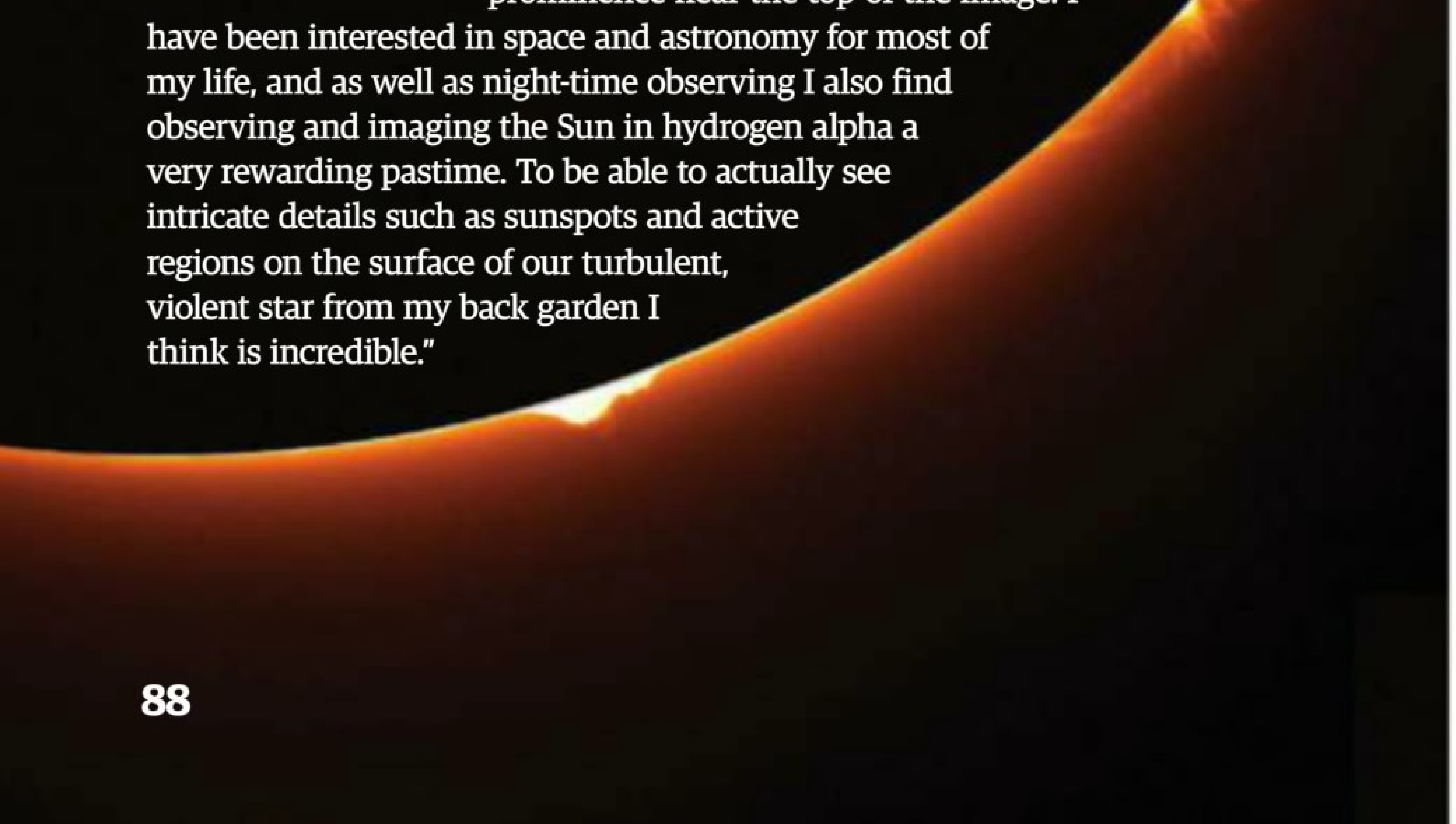
Send your astronomy photos and pictures of you with your telescope to **photos@spaceanswers.com** and we'll showcase them every issue

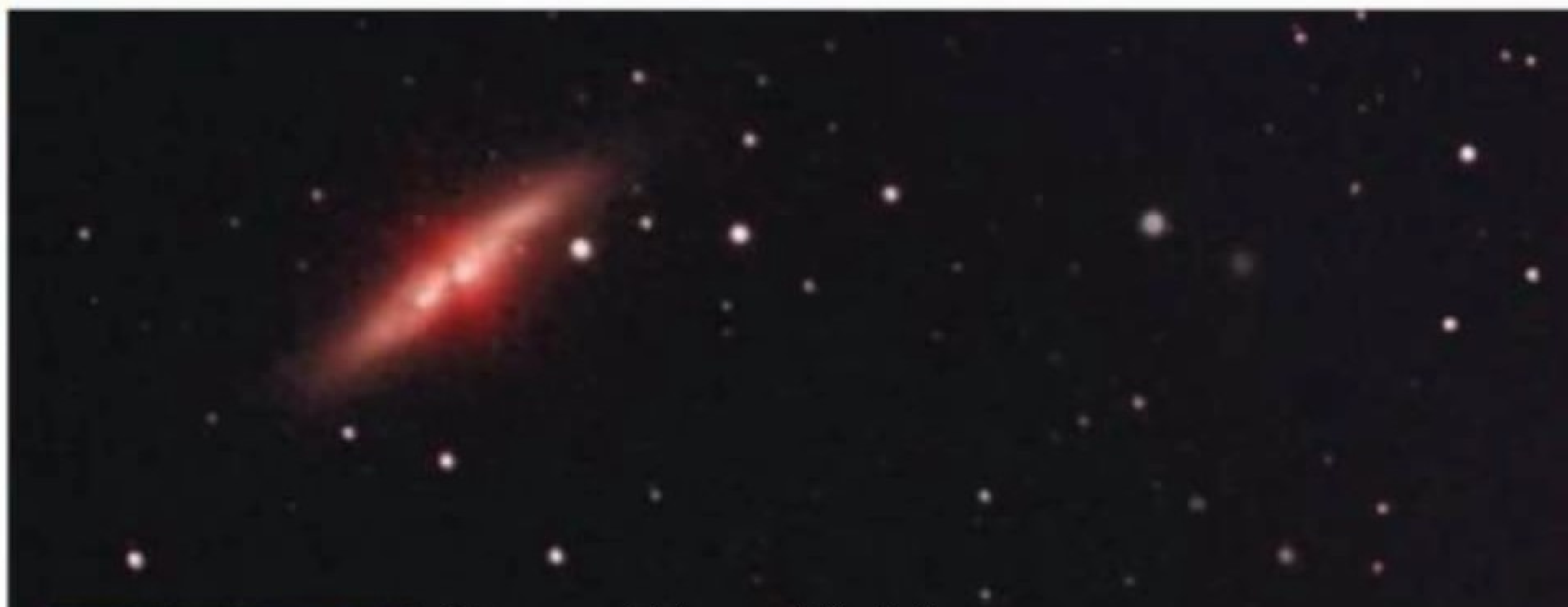
John Brady,

Lancashire

Telescope: Coronado Solarmax 60 II

"This image was taken on 27 February 2013 and shows solar prominences on part of the Sun's limb. I have blacked out the major part of the solar disc to highlight these multiple Earth-sized eruptions, also see the detached prominence near the top of the image. I have been interested in space and astronomy for most of my life, and as well as night-time observing I also find observing and imaging the Sun in hydrogen alpha a very rewarding pastime. To be able to actually see intricate details such as sunspots and active regions on the surface of our turbulent, violent star from my back garden I think is incredible."





Steve Mansfield,

Lancashire

Telescope: ED80 DS-Pro on a HEQ5 Pro

"This is the first image I've taken with this scope and mount. I took it from the light-polluted skies in Preston, Lancashire with a total exposure time of four hours [showing the M81 and M82 galaxies]. I have been interested in astronomy all my life since my father bought me a 70mm reflector when I was 12. I am now 23 and last year I took the plunge and decided to combine my two hobbies, astronomy and photography. I am still riding a very steep learning curve but enjoying every minute of it!"

Scott Prideaux,
Stoke-on-Trent
Telescope: SkyWatcher 200P Explorer

"My interest in astronomy was ignited after seeing Brian Cox (*Wonders Of The Solar System/ Universe*), and I was given a SkyWatcher 200P Explorer for a landmark birthday. The first time I looked through the eyepiece I knew this would not be a passing phase. On that first night I held my mobile phone to the eyepiece and got my first pictures of the Moon. That's when I decided astrophotography was the way for me, although I still love visual astronomy. I took this photo of the Milky Way in September 2012 while in Australia."

Charlotte Lamb,
Tyne and Wear
Telescope: N/A

"Although I have not yet purchased an astronomy telescope I thought I would share a photograph I recently took while in Northumberland. Armed with a small pair of binoculars and a spotting scope I hoped to catch sight of Asteroid 2012 DA14. Unfortunately the English weather once again let me down. Rather than go away empty-handed I sought out another clear area of sky and captured this beautiful image of Jupiter and the Pleiades Cluster with the glow of the Moon. I would love to see my picture published in your magazine to which I am subscribed and look forward to each month."

Charlotte took her awesome photo while she was in Northumberland

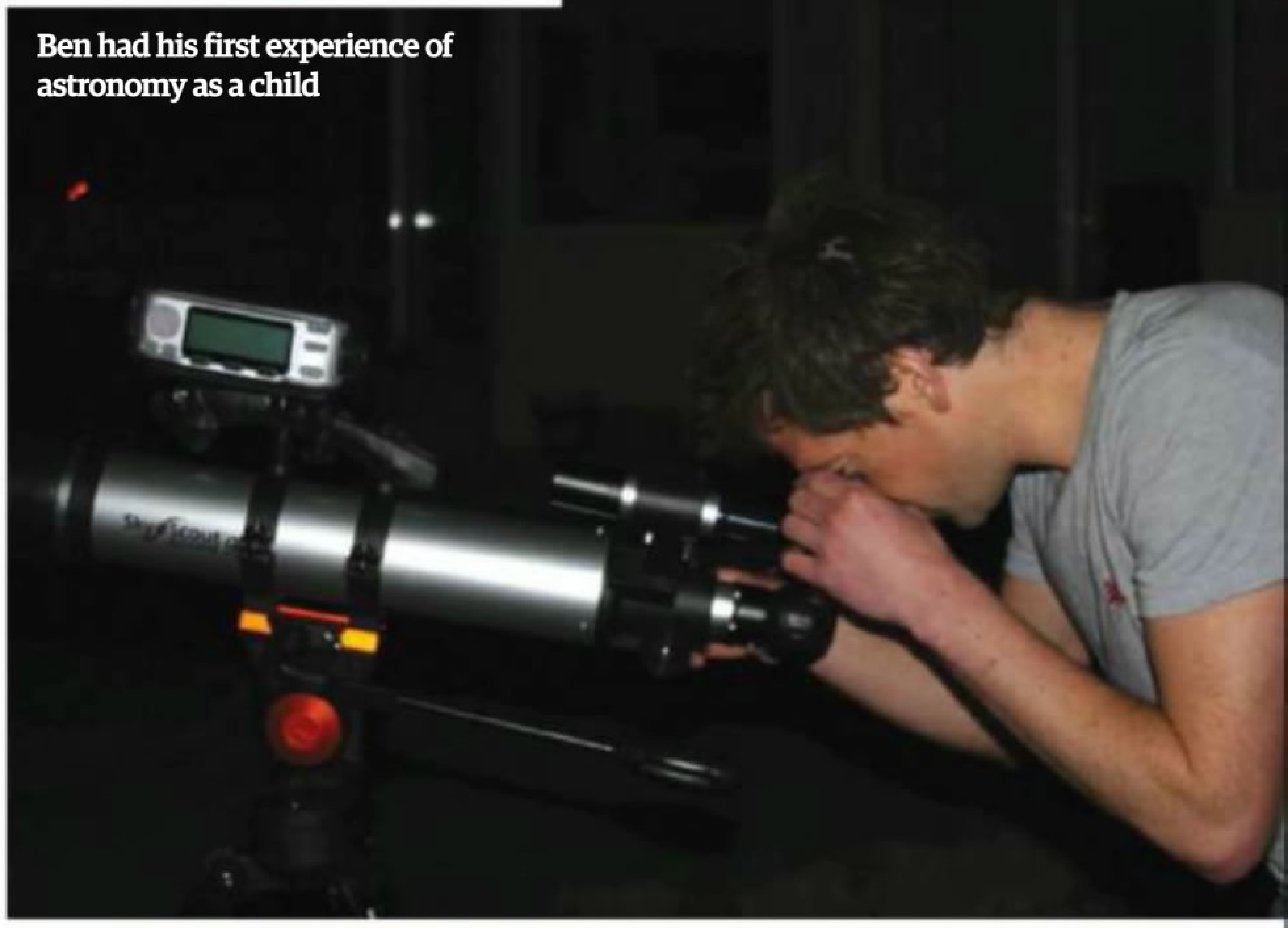
Send your photos to… @spaceanswers @ photos@spaceanswers.com

Me & My Telescope

First-time astronomers

Two novice stargazers tell us how they got on with their first go at astronomy

Setting up the SkyScout 90 is very easy



Ben had his first experience of astronomy as a child

Celestron SkyScout Scope 90

Tested by: Ben Johnson

Cost: £180

From: www.hama.co.uk

"When I was younger I had a glance through my dad's telescope once and, much to my amazement, was able to see the rings of Saturn. It was fascinating. But sadly, since then, I've never had the time or dedication to actually have a go myself.

"So, recently, I finally decided to get my hands on a telescope. I'd already been given a SkyScout Personal Planetarium as a present (which retails for around £250), so I decided to go with the relatively low-cost SkyScout Scope 90 that accompanied the Personal Planetarium.

"The day it arrived I felt like a kid again. I eagerly unboxed the whole thing and read through the instructions. Setting it up was incredibly easy, and I had it ready and waiting to go in my conservatory in no more than 20 minutes.

"I then had a painstaking wait for some clear skies but, when they eventually came, I hurried outside and trained my telescope on the heavens. This telescope isn't computerised but using the Personal Planetarium you can easily navigate your way around the sky. Using the handle and focuser I gradually toured the night sky, with the Personal Planetarium as my guide.

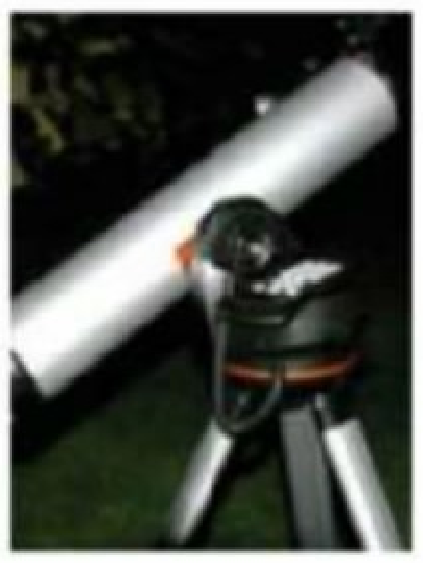
"The clarity I was able to get on some objects was amazing. I was fortunate enough to have Jupiter in the sky, and I was able to get a decent view of the planet and even, I think, its four moons.

"Since then I've had a few more opportunities to use the telescope, each as thrilling as the first. Based on these early experiences I'll be returning to astronomy again and again, hungry for more." ●

The SkyScout Personal Planetarium is designed to be used with this telescope

The SkyScout 90 looks great and is easy to use

Celestron LCM 76



Tested by: Lucilla Garrow
Cost: £300
From: www.hama.co.uk

"Getting into astronomy has been something that I've been interested in doing for ages. I've got quite a few friends that regularly do astronomy, and they've always tried to get me involved.

"It wasn't until a few months ago that I had a look through one of their telescopes. I'm not quite sure what we were looking at but whatever it was, it was amazing. So, I decided to finally splash out and get my own telescope to see what all the fuss was about.

"I wanted something that was easy to use for an amateur and also not a chore to set up, so I went for this computerised Celestron telescope as I heard it was good value for money and also simple for an amateur like me to get their head around.

"On my first night it took me a while to get to grips with the telescope's alignment technology. It took me a good half an hour to figure out exactly what I was supposed to be doing, but once it was properly aligned I was raring to go.

"Using the controller I spent most of the evening just browsing across the night sky. I looked at too many things to list all of them here but I managed to see some pretty cool deep sky objects, some of the planets, and of course I took a good look at the Moon.

"The views I was able to get were considerably better than I expected, and I was really surprised at the quality of what I was seeing through the eyepiece.

"I can't wait to go out again in future and have another try. I might even try my hand at astrophotography at some point, which is something I've wanted to do for a while. All in all, I loved using this telescope and would recommend it to someone looking to get started in astronomy." ●

> "I wanted something that was easy to use for an amateur and also not a chore to set up"

Once the telescope is properly aligned you'll be viewing the night sky in no time

The computerised functionality is ideal for amateurs

This telescope has surprisingly good optics

Lucilla plans to try her hand at astrophotography next

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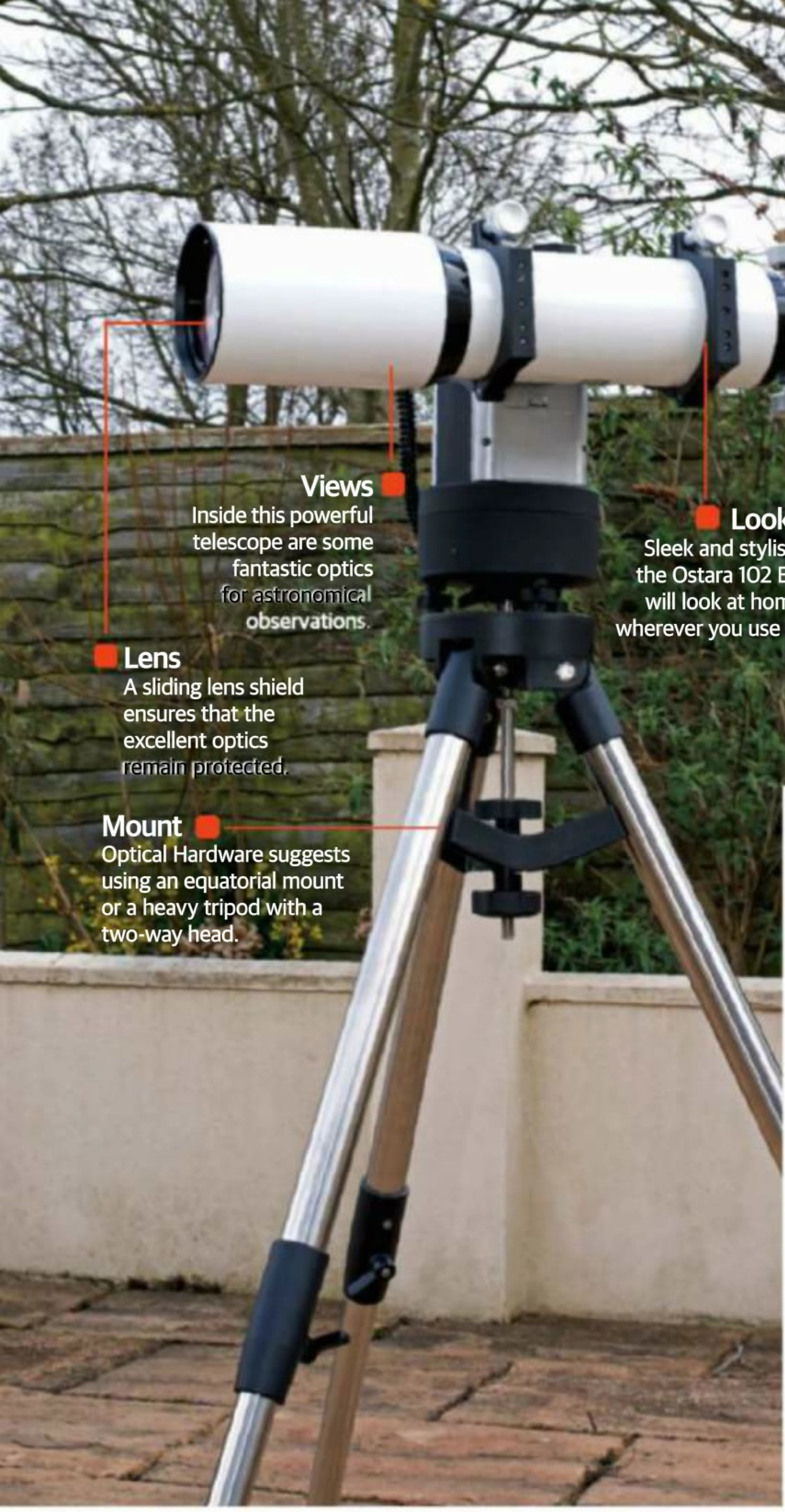
Telescope advice

This excellent scope is perfect for astronomers looking for a high-end upgrade



Views
Inside this powerful telescope are some fantastic optics for astronomical observations.

Looks
Sleek and stylish, the Ostara 102 ED will look at home wherever you use it.

Eyepieces
This telescope accepts both 2" and 1.25" eyepieces and accessories.

Lens
A sliding lens shield ensures that the excellent optics remain protected.

Mount
Optical Hardware suggests using an equatorial mount or a heavy tripod with a two-way head.

We used the Ostara 102 ED on an iOptron Minitower tripod

The optics offer incredible quality, as you would expect for the price

Ostara 102 ED

Cost: £999/$1,500
From: www.opticalhardware.co.uk
Type: Refractor
Aperture: 102mm
Focal Length: 700mm
Magnification: N/A

The Ostara 102 ED is a simply gorgeous telescope that will astound anyone who can afford the somewhat hefty price tag. With first-rate optics, a beautiful finish and surprisingly good portability, this is a great choice for a more experienced astronomer who wants to take their viewing experience to the next level.

You'll need to purchase a separate tripod or mount as the Optara 102 ED's £999 price tag does not include a mount, only the telescope itself. During our review we used the telescope on an iOptron Minitower (www.altairastro.com), but it will fit on most mounts; just make sure you check the specifications before buying to ensure your mount will be able to hold it. Brackets are supplied so that you can fit the telescope.

Supplied in a sturdy foam case, for easy transport, the multi-coated lenses of the Ostara 102 ED are exceptionally good quality. The exterior, made of aluminium, is lightweight but doesn't feel cheap, especially as they've been hand-finished. Also supplied are a finderscope (with mount and bracket) and a 90-degree prism.

The real joy of this scope is actually using it, though. From deep sky objects to planets, you'll be getting crisp and sharp views that cheaper all-in-one telescopes simply cannot match. If you are looking to upgrade from an existing telescope, or want to start your hobby in astronomy with a bang, then definitely check this out. ■

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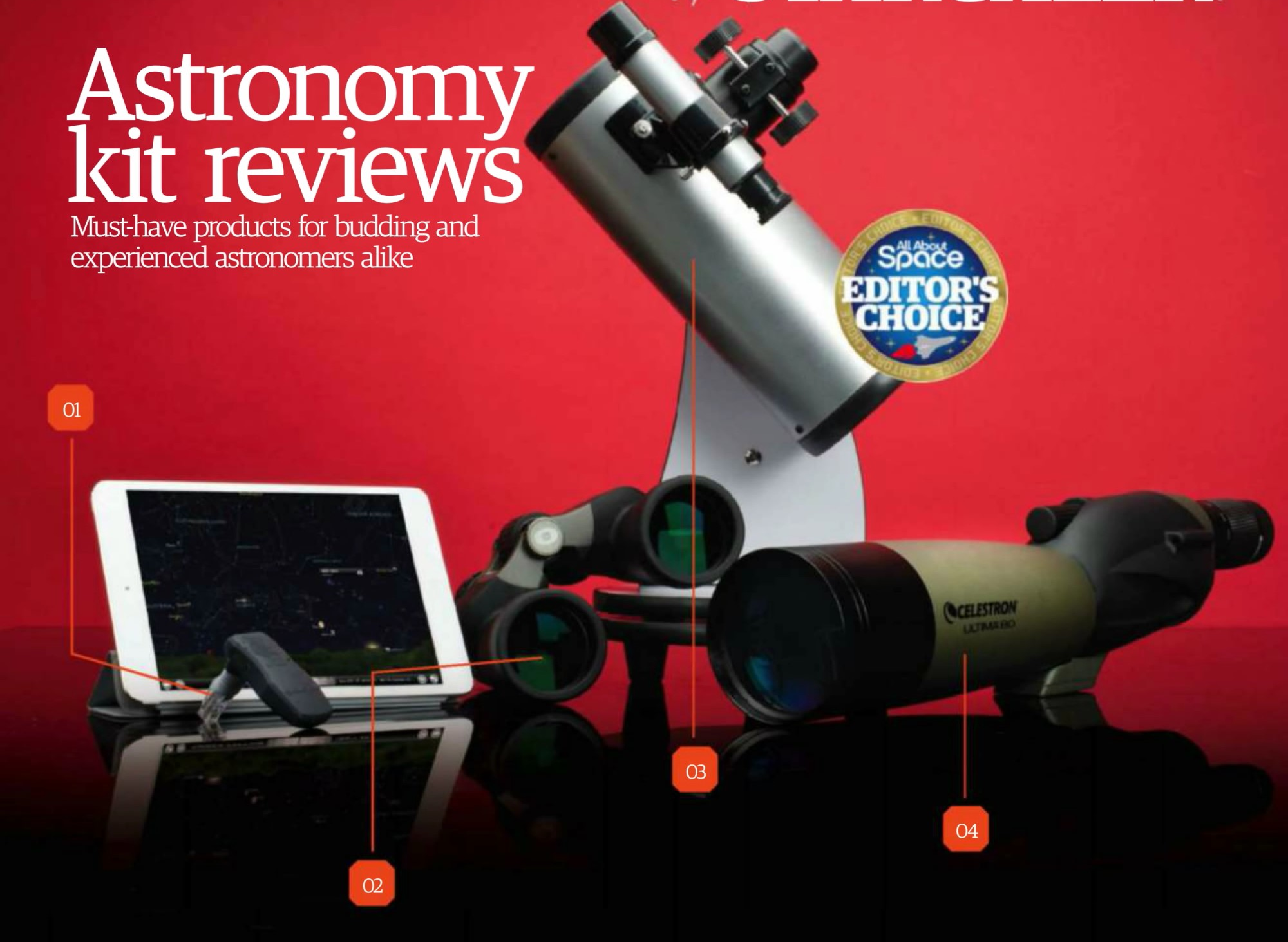

1 Wi-Fi Adapter
Celestron SkyQ Link

Cost: £125/$190

From: www.hama.co.uk

Celestron's SkyQ Link Wi-Fi Adapter allows you to use your iPhone or iPad instead of a hand controller to wirelessly move your computerised telescope. It's a nice piece of kit by itself, but it's best used in conjunction with the Celestron SkyQ App. Plug in the SkyQ Link adapter and once you've aligned your telescope this will allow you to use the app to slew to objects in the night sky simply using your iOS device. You can even prepare the telescope from the warmth of your own home if you like before wandering outside to take a look at the night sky. The SkyQ Link is very useful, and it can make a welcome change from using a hand controller. We'd definitely recommend checking this out.

2 Binoculars
Ostara Elinor 10x50

Cost: £200/$300

From: www.opticalhardware.co.uk

This fantastic pair of binoculars does a superb job of giving you a crisp and clear view of the night sky. Included with a soft case and protective rubber caps, the Elinor 10x50s couple great optics with comfort; the binoculars are rubber coated, so you'll have no problem gripping them. They're not too heavy either, so prolonged viewing shouldn't be too much of a problem. For observing galaxies, planets and more this is an ideal pair of binoculars. We were able to get wonderful views of the Andromeda Galaxy, the Moon and much more while looking through them. They'll be accompanying us on our astronomy trips in future for some quick observations when we're not using a telescope.

3 Starter scope:
Visionary First View

Cost: £50/$75

From: www.opticalhardware.co.uk

If you want a cheap and easy way to get yourself, a loved one or a friend into astronomy then look no further than the Visionary First View starter scope. It sits on a sturdy stand that you can rotate, while a dial on the side allows you to alter the angle at which it is pointing. It is supplied with two eyepieces for different levels of magnification, x24 and x75, while a finderscope helps you point the scope in the right direction. Twisting the focus knob will give you crisp views of night sky objects. Overall, this all-in-one piece of kit is the perfect companion for those new to astronomy, or even the more experienced astronomers looking for a tabletop telescope.

4 Spotting scope
Celestron Ultima 80

Cost: £200/$300

From: www.hama.co.uk

This excellent spotting scope is an ideal choice for astronomers looking for something portable. It produces an incredibly sharp image and is very easy to focus, so however you set it up you'll have no problem getting a great view of the night sky. In fact, its length means that you can even use it without a tripod (provided you've got a steady hand) to get some great views. The 80mm aperture also does a good job of collecting light, so you'll be able to make out a considerably large number of celestial objects. The Celestron Ultima 80 comes with a carry case, lens covers and an eyepiece, although there is no tripod unfortunately, but all in all it's a fantastic package.

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Shepard is picked up after splashing down in Freedom 7 in 1961

Alan Shepard

The first American in space and fifth man on the Moon, Alan Shepard was a true pioneer of space exploration

Alan Bartlett Shepard, Jr was born on 18 November 1923 in Derry, New Hampshire, USA. He had an illustrious career with NASA from 1959 to 1974, becoming a pioneer of manned space exploration, before launching a successful business career and eventually passing away on 21 July 1998 due to leukaemia.

After graduating from the Admiral Farragut Academy military school in 1941, he embarked on a career with the US Navy and in 1947, after serving in World War II, he received his Naval Aviator wings. He began high-altitude tests in various aircraft, spending more than 8,000 hours in the air with almost half of those in jets.

In 1959, he was invited to join NASA, along with over 100 other test pilots, as part of the first group of astronauts. After tough physical and psychological tests he was selected as one of seven Mercury astronauts and, as the standout candidate from the group, he was chosen for the first American manned space exploration mission in January 1961.

Originally scheduled to lift off in late 1960, the flight was delayed several times for additional work on the spacecraft until it eventually took off on 5 May 1961, almost four weeks after Yuri Gagarin had become the first human in space. Despite being only the second man in space, and not the first as had been intended (Gagarin's successful flight came as somewhat of a surprise), Shepard was instantly cemented into history as the first American into space. His flight was brief, a 15-minute suborbital flight that took him to an altitude of 187 kilometres (116 miles). Unlike Gagarin, however, Shepard had some manual control of his spacecraft.

In 1964, Shepard was diagnosed with Ménière's disease, which can cause disorientation, dizziness and nausea. As a result, he was grounded for the Gemini programme, taking up the role of Chief of the Astronaut Office instead. In May 1969, his flight status was restored, and he made his second flight into space as the commander on board Apollo 14 in early 1971. This mission was the first to broadcast colour footage from the Moon, and Shepard also famously hit two golf balls on the Moon.

After returning from his lunar landing mission he returned to the role of Chief of the Astronaut Office, before retiring from both NASA and the Navy in 1974. He went on to found his own company, Seven Fourteen Enterprises, Inc and in 1994 he published *Moon Shot: The Inside Story Of America's Race To The Moon*.

Shepard received numerous awards and has been honoured in various ways thanks to his pioneering astronaut work. He was awarded the Congressional Space Medal of Honor by President Jimmy Carter in 1978, was inducted into the US Astronaut Hall of Fame in 1990, while his hometown Derry was given the nickname Space Town, among many other accolades and awards.

Shepard died in 1998, and his wife of 53 years passed away just five weeks later. They were survived by three daughters and six grandchildren. The first American in space will remain ingrained in the history of space exploration, pioneering a generation that ultimately led to the Moon landings that he himself participated in. He will be remembered as one of the great American space heroes long into the future. ■

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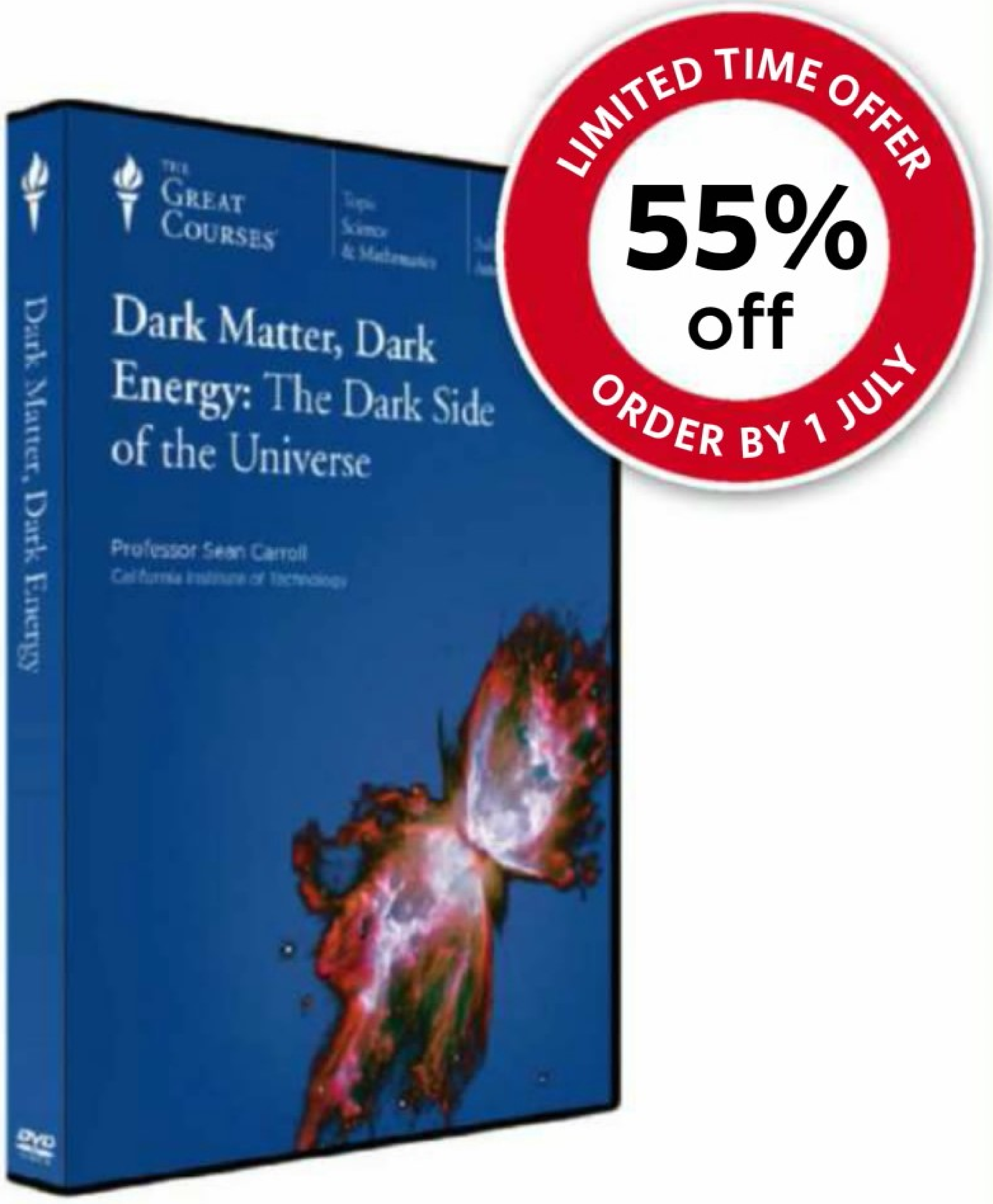

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